

BANDKNIFE SHEARING OF WOOL FIBRES

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BAND KNIFE SHEARING OF WOOL FIBRES

ABSTRACT

The separation of the wool and the skin is an important step in the processing of lamb and sheepskins in New Zealand Freezing Works.

The chemical depilatory process used at present has a number of disadvantages. It has been calculated that substantial benefits to the freezing industry would accrue if this process was replaced by a mechanical wool removal system, which left a short stubble of wool on the skin.

Initial investigations indicated the suitability of a continuous bandknife machine for cutting the wool. This thesis describes the investigation of both the cutting and skin handling processes, the building of experimental machines, and the testing and development proceeding from this.

Model and small scale machines were built to investigate proposed systems, and two full size experimental machines were constructed. These machines were developed to the stage where reliable cutting was achieved. Although the length of stubble remained uneconomically long, it was considered that further development could overcome this.

The cutting process was investigated by means of miniature, single fibre cutting machines. The technique of using high speed photography to record the brief cutting event while observing the fibre through a microscope was developed.

NOMENCLATURE

The names given to some objects and machines described in this thesis could be ambiguous. A standard vocabulary for objects having a number of names, or a common name, has been used.

A WOOLLY SKIN is a sheepskin which has wool left on it. Skins to be processed by the shearing machine are in this category.

The PELT is the skin of a sheep with the wool removed, or with only a stubble left.

The FLEECE is the collective name for the wool fibres after they have been removed from the pelt.

Confusion arises when bandknives are described because the cutting blade itself and the entire machine can both be referred to as the bandknife.

In this thesis the machine, as a whole, is referred to as the BANDKNIFE MACHINE. The cutting blade is simply called the BLADE.

Although bandknife blades do not use a shearing action to cut (unlike hand-held shearing machines), it has become the practice in the industry to refer to any wool cutting machine as a SHEARING MACHINE. Likewise in this thesis removal of the fleece, except for a short stubble, is referred to as SHEARING and a pelt so processed is called a SHORN pelt.

A SHEARLING PELT is a woolly skin which has been trimmed to a wool length of around one to two inches.

CHAPTER I

BAND KNIFE SHEARING OF WOOL FIBRES

INTRODUCTION

Each year, over thirty five million sheep and lambs are slaughtered in New Zealand. Wool reclaimed from the skins of these animals accounts for about ten percent of the total national wool clip. The skin, or pelt as it is known, is used in shoe and garment leather.

The early stages of skin processing are usually carried out in fellmongeries, which are generally in the same buildings, or building complexes, that process the carcasses, i.e. the ubiquitous New Zealand freezing works.

In recent years, dewooling has been carried out using lime-sulphide depilation, in most freezing companies. The main constituent of wool, keratin, is particularly susceptible to attack by this chemical, while the collagen of the skin is relatively resistant.

When a paint, consisting of a mixture of lime and sodium sulphide, is applied to the flesh side of the skin, the mixture slowly diffuses through the skin, dissolving part, or all, of the wool roots. The wool can then be easily removed, by pushing with the hands, or using a 'pulling' machine. Most commonly, the wool is removed from the skins manually. The skin is laid on a board, sloping away from the worker, who pushes the wool off the skin with a blade, or using his hands. The wool is usually classed for length, fineness, etc. as it is removed.

Although this system has found general acceptance, being superior to any method previously devised, it does have several disadvantages :

- (a) The wool is often left contaminated with lime, or even damaged by the depilatory action;
- (b) Because the pelts are left stacked for some eighteen to twenty four hours to allow depilation to occur, damage resulting from overheating of the pelts in the stack is possible;
- (c) Depilation is a batch process, with inherent handling and storage problems;
- (d) Wool removal, or pulling (as it is known), is a physically demanding job. Older men often find themselves unable to withstand the rigours of the job, whereas the younger workers are unlikely to be such competent wool classers.

Predictions have been made of the economic advantages of replacing sulphide depilation with a mechanical cutting system, leaving a short stubble of around one quarter of an inch. From work undertaken at the Wool Research Organisation of New Zealand, Mr R.G. Stewart predicted that the freezing industry would gain NZ\$3.6m per annum if mechanical wool removal could be achieved.¹

Although many New Zealand sheep are crossbred and have a more coarse wool than such sheep as the Merino, which has been bred as a wool producing animal, the wool is still in demand. The presence of depilatory contamination is causing concern in some markets, and this concern was another reason for using mechanical wool removal.

Preliminary design studies of a mechanical wool removal machine were carried out by final year Mechanical Engineering students at the University of Canterbury. These studies indicated that a continuous bandknife was a possible cutting device, aided by other systems for holding the skin during cutting. It was clear that investigation in the field of mechanical cutting of wool fibres was necessary before machines could be installed in freezing works.

This thesis is the account of those investigations, and the development of bandknife shearing machines.

1.1 OBJECTIVES OF THE PROJECT

The ultimate aim of work in this field is the production of an economically viable raw skin shearing machine. The aim of this project was to carry out investigations into the cutting of the wool, and the handling of the skin.

Because of the aim of producing a machine, this investigation was viewed as an example of applied research. Consequently, many phenomena observed while testing machines were not investigated, unless they directly affected further development.

Furthermore, the economic advantages of using shearing machines in the freezing industry as opposed to using the depilation process changed from time to time as the wool prices being obtained changed. This could, and did, affect the type of handling process used.

The problem was approached in two ways :

- (a) An investigation of the cutting process itself

was carried out, using both macroscopic and microscopic techniques;

- (b) The cutting devices and handling systems were tested in a series of experimental machines.

1.2 REQUIREMENTS OF A SKIN SHEARING MACHINE

The main requirement was that the wool be severed from the skin, leaving as little stubble as possible and without damaging the wool or the pelt.

The maximum amount of wool which could be left on the skin varied, according to the fluctuating prices of wool, but in general an average length of between one quarter and three-eighths of an inch was acceptable.

The financial analyses of wool shearing had assumed a throughput of 600 skins per hour. This figure was near the average rate at which skin trimming and depilatory spraying was done.

An important requirement was that the shorn fleece remain a complete unit. Mixing of wool fibres from different areas of the skin was not desirable, because classing was then more difficult, and less rapid.

It was desirable that the machine require no special skills to operate, as it was intended to introduce this machine to a production line employing unskilled labour. Because of the adverse conditions under which freezing works machines operate, the shearing machine was required to be rugged and corrosion resistant. The need for continuous operation was a further requirement. However, twenty-four hour operation was not expected, as most New Zealand freezing works operate no longer than twelve to fifteen hours a day.

1.3 A REVIEW OF EXISTING RAW SKIN SHEARING MACHINES

Initial investigations carried out by the Wool Research Organisation of New Zealand, and correspondence with users and agents of existing machines, were expanded in 1971 by Mr R.G. Stewart on his visit to the United States and Europe, and by the author who visited the United States in 1974.

The following list of commercially built machines was known in 1971. A further machine, built in the United States was viewed in 1974. This is described in the Appendix, because this thesis, as far as possible, has been laid out in chronological order.

W.P.M. (Württ Pelzmachinenfabrik): The W.P.M. raw skin shearing machine is used in a few New Zealand fellmongeries, primarily for the trimming of shearling pelts. A diagrammatic representation of this machine is shown in Figure 1.

The woolly skins are held on a woven wire mesh conveyor belt, by the suction effect of an evacuated plenum chamber beneath the belt. A bandknife is used to cut the fibres, and a centrifugal fan produces an airflow which bends the fibres over the blade and transports them into a chute.

Although this machine performs the task of trimming to a suitable length of around one inch with reliability, its ability to cut to shorter lengths is very much dependent on the operator's skill, and on the uniformity of the skin thickness.

The throughput is lower than required. Under favourable conditions two hundred skins per hour could be processed. This was considered inadequate.

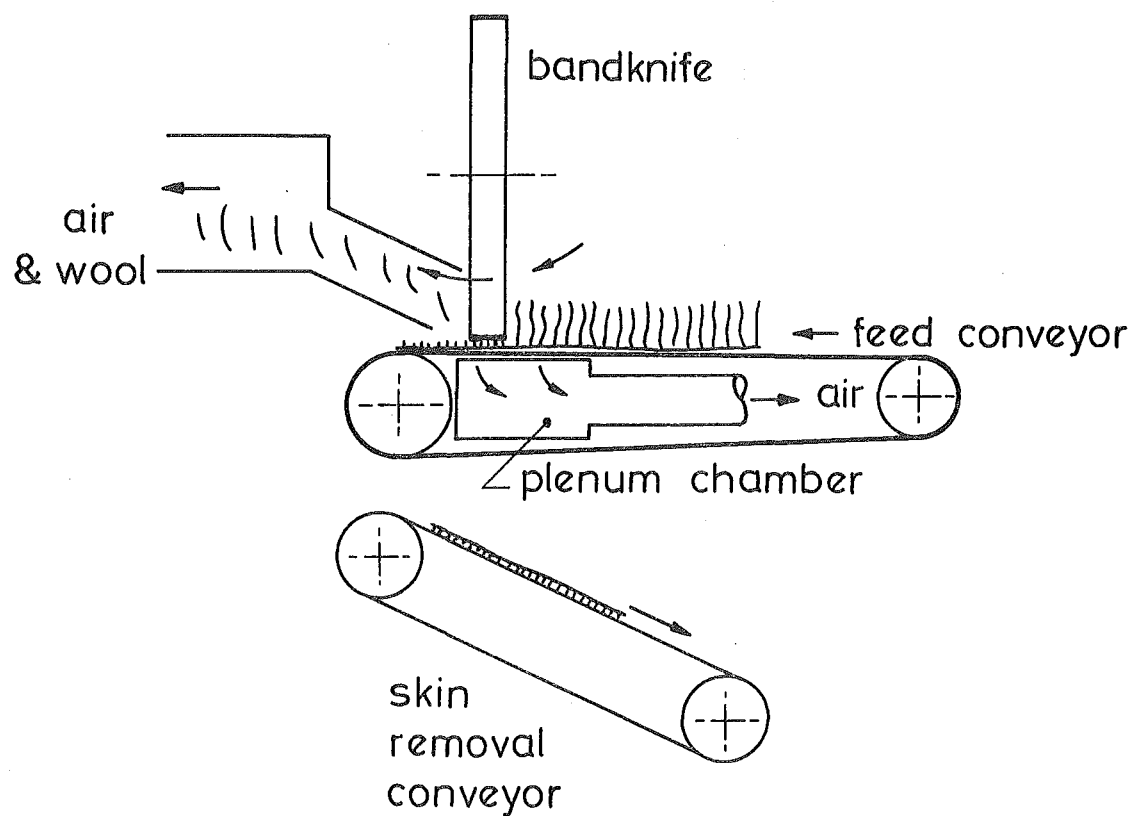


Fig 1 WPM RAW SKIN SHEARING MACHINE

The severed wool is not kept as a fleece. However, the machine is rugged and reliable.

As the manufacturer was not prepared to assist development in any way, it was decided that the W.P.M. machine was not a suitable machine for development work.

Mercier-Freres: The French firm of Mercier-Freres produce splitting machines for the tanning and plastics industries, as well as other fellmongery machinery. At the time of investigation, this firm was carrying out wool shearing experiments, and were reluctant to co-operate with this project.

Fecken-Kirfel: Fecken-Kirfel is a German firm producing bandknife splitting machines for the plastics industry. Their attempts at wool cutting had proved unsuccessful, and consequently they were reluctant to do any further experimenting.

McNeil-Femco: Femco bandknives are manufactured in Cuyahoga Falls, Ohio, by the Falls Engineering Company, a division of McNeil Corporation. The company supplies much of the United States plastics industry with splitting machinery.

Wool cutting experiments had been carried out at Cuyahoga Falls, with promising results. However, the number of sheep slaughtered per year in the United States is not large, and the development of raw skin shearing machines was not considered economic.

During visits to the plant by Mr Stewart and the author, a great deal of useful technical data was forthcoming. When the full-scale raw skin shearing machine was constructed at the University of Canterbury, the purchase of a McNeil-Femco bandknife was considered. However, as detailed in Chapter

VIII, Section 2, it was decided to construct a bandknife in the Department workshops.

Selbeck: This German-made machine is similar in principle to the W.P.M. in that a porous belt transports the skin, and air is taken from an area below the bandknife, creating a band of suction to hold the skin against the belt. The cut wool is picked up by a conveyor, which has a small diameter end roller mounted just above the blade. Unlike the W.P.M., the Selbeck machine keeps the cut fleece intact. (See Figure 2).

The only Selbeck machine in New Zealand was being operated by a firm producing shearling pelts and artificially backed fleeces. The process of trimming the wool, and glueing the cut fibres to a plastic sheet was developed by the Wool Bureau of New York. As this was a classified project, it was not possible to view the machine. However, it was claimed that the machine could cut to stubble lengths of one quarter of an inch, but at slow (150 per hour) rates.

1.4 DISCUSSION

None of the machines described were considered to be satisfactory by the freezing companies in their present state. Consequently, it was decided that a programme of experimentation and eventually design of a full scale machine would be carried out.

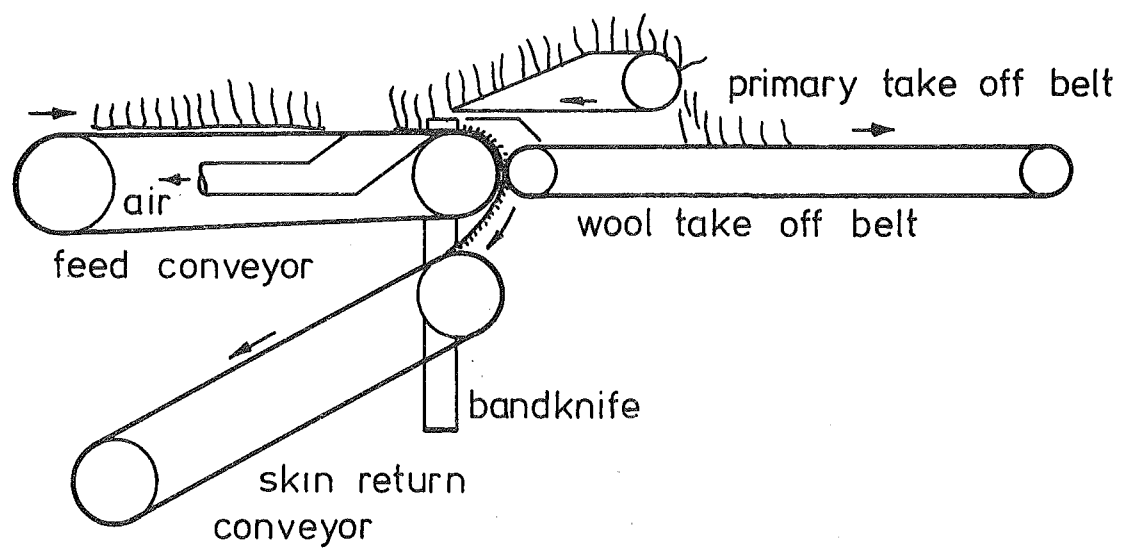


Fig 2 SELBECK RAW SKIN SHEARING MACHINE

CHAPTER II

INITIAL INVESTIGATIONS

II.1 GENERAL DISCUSSION

Before design of a shearing machine could be attempted, it was apparent that some knowledge of required speeds, powers etc. was required.

After examining the performance of a number of commercial machines (refer to Introduction), it was realised that, in order that a machine might meet the specified throughput requirements, it would be operating at speeds not approached by any existing machines. Consequently it was decided that a small test wool cutter would be built to determine some of the necessary parameters. The use of a small scale machine avoided the high costs and longer construction times of a larger device.

II.2 DESIGN OF THE EXPERIMENTAL MODEL

As it was estimated, from observation of existing machines, over five horsepower was needed to cut the wool from a skin at the desired rate, a machine cutting only a thin strip of woolly skin was needed.

The construction of a small scale bandknife did present many problems, because it was difficult to construct a blade, and equally difficult to obtain one. Consequently, it was decided to cut with a sharpened disc, because the radius ratio of a fibre to even a small disc is of the order of 10^3 .

It was not necessary for this machine to have a contin-

uous feed-in system. As the main object of the test was to investigate the cutting phenomena, holding systems, which were quite impractical for production machines, were satisfactory for this device.

Provision was made for the measurement of power input to the knife, and the speed of the knife.

II.3 DESCRIPTION OF THE MACHINE

The cutting device was a steel disc ((A) in Figure 3) which was four inches in diameter, and one eighth of an inch thick. The edge was sharpened in the form of a double bevel. A vertical shaft (B), carried the disc. Tapered housing ball bearings (C), supported the shaft and drive to the shaft was by vee belt and pulley (D). The drive motor (F) was a one tenth horsepower universal motor driving the shaft and disc through a step up ratio vee-drive of three to one. A silicon controlled rectifier speed control was used. Maximum unloaded speed was 7000 r.p.m. at the motor shaft, giving a blade edge speed of 360 feet per second.

A tacho-generator measured the drive motor shaft speed.

The motor was mounted in trunions (E) which enabled it to rotate around its drive shaft axis. A Cantilever restraining arm (G) was fitted with strain gauges, so that the surface strain, and hence the motor torque, could be measured.

The one inch wide woolly skin samples were stapled to a rubber feed in belt (H), which passed under the cutting disc. The length of residual stubble was varied by moving the motor and blade unit supports up and down.

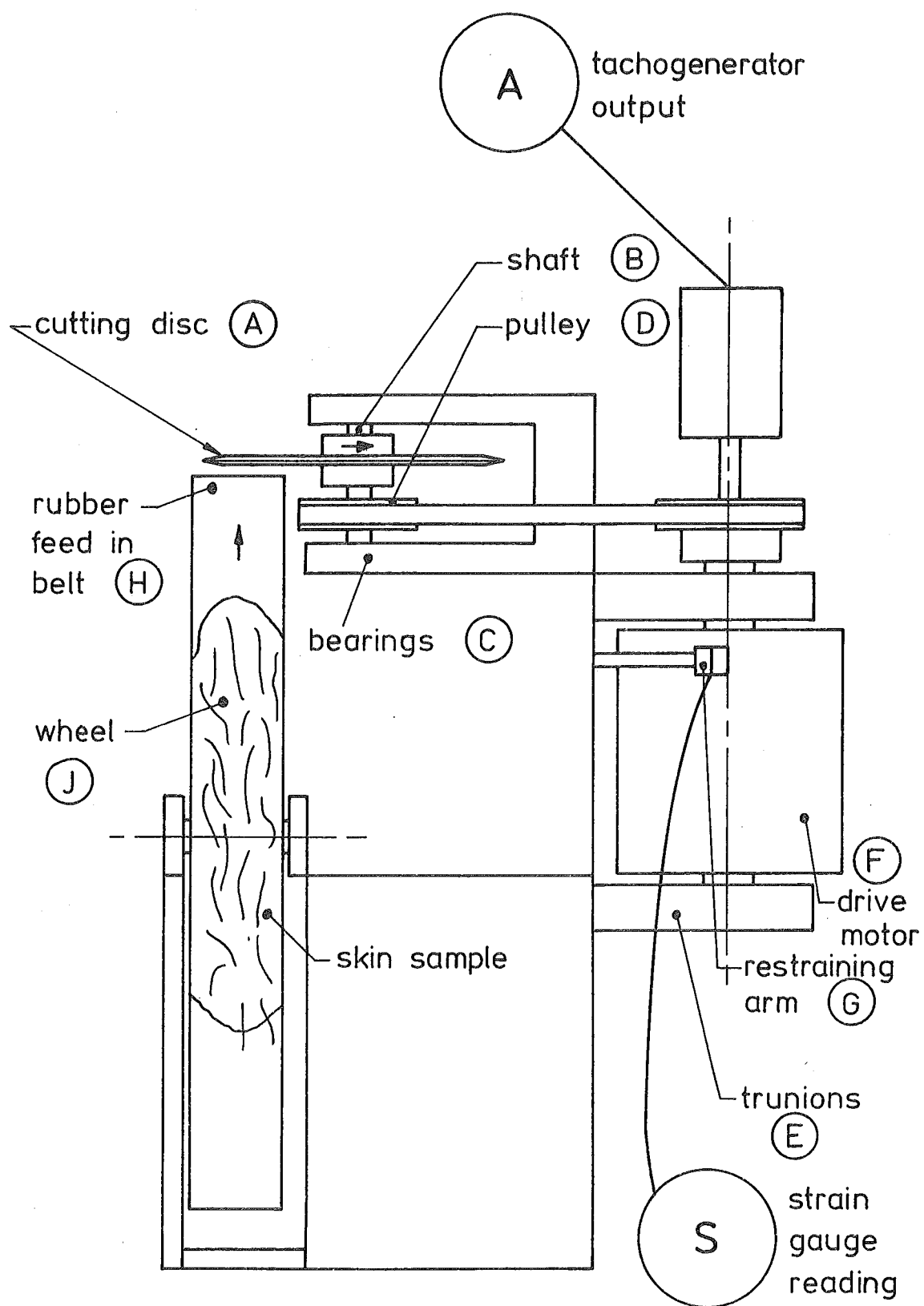


Fig 3 MODEL WOOL CUTTING MACHINE

Wooden wheels (J) of eight inch diameter, were the conveyor end rollers. Although smaller wheels could have been used, it was expected that other belts than the thin rubber eventually used might be tested on this machine, and would require a greater radius roller.

The feed conveyor was driven by another, one tenth horsepower motor, through a worm gear reduction gearbox.

II.4 TESTING PROCEDURE, AND OBSERVATIONS

Before test runs with woolly skins were carried out, the tachogenerator and strain gauges were calibrated. A stroboscope was used to measure the motor speed over a range of speeds, while the tachogenerator output was recorded.

The torque was calculated from the strain gauge reading using bending theory. A no-load run was done to measure the power consumed in friction, windage, etc.

Calibration curves for the tachogenerator and no load input may be seen in Appendix 1.

In a typical test run, the blade was started and the stapled-down skin fed under it. Despite a negative feedback control system on the motor, the disc speed invariably fell to a steady speed below the original setting. In some cases, at lower speeds, stalling of the disc occurred. The steady state speed achieved with higher initial speeds was reached before more than an inch of the skin had been cut, at normal feed-in speeds.

It was immediately apparent that the power needed to

drive the disc had been underestimated, and consequently the lower speed (and, unavoidably, reduced torque) readings were not reliable. The disc often stalled. The feed-in mechanism also had inadequate power to drive the skin samples under the blade. Then drag of the stubble on the underside of the blade was evidently greater than expected.

Other effects were noticed. The blade quickly lost its edge, and then no longer cut the fibres. The wool fibres tended to bend over away from the disc edge, and were then dragged under the disc. This additional drag on the disc increased the tendency for the motor to stall.

II.5 MODIFICATIONS TO THE MACHINE

The mild steel disc originally used was replaced by a slitting saw from a milling machine. The teeth were ground off, and a double bevel edge was machined and sharpened. The hardness of this blade was 1000 on the Vickers Pyramidal System, compared to the original blade of 450 VPN.

It was felt that a harder blade which kept its edge longer would require less power to drive. In practice this blade also lost its edge quickly, although not as rapidly as the mild steel disc.

It was apparent that the stubble drag on the blade absorbed a significant proportion of the power, and was not typical of a bandknife drag because of the greater contact area. This was partly due to the bending of the fibres during cutting, with a consequent increase in stubble length.

Guards were fitted to the sides of the feed belt to

prevent sideways bending of the fibres. Because of the size of the skin sample, edge effects were more apparent than would be in a machine cutting right across an entire woolly skin.

Increasing the power inputs to both the cutting disc and the feed-in belt was difficult, especially the input to the disc, because the drive motor was mounted on trunions. In view of the amount of rebuilding needed, it was decided not to increase the power, but to learn as much as possible from the machine as it was.

II.6 TEST RESULTS

The curves of power and torque against disc edge speed for a sharp edge, are shown in Figure 4. A minimum speed of around fifty feet per second was necessary to ensure cutting at the feed-in rate used. (This rate was reduced from the designed speed (nine inches per second) to four inches per second because of the insufficient power). In order to achieve a throughput of 600 skins per hour, a feed-in speed of nearly one foot per second is needed. (Approximately one skin every four seconds).

With the reservation that the feed-in speed was lower than desired, the power needed to cut at speeds above the minimum cutting speed was calculated. The strain gauge readings were converted to torque values using the system constants and the power required to cut the wool from a strip of skin was calculated. From this figure the power required to cut across an entire skin was obtained.

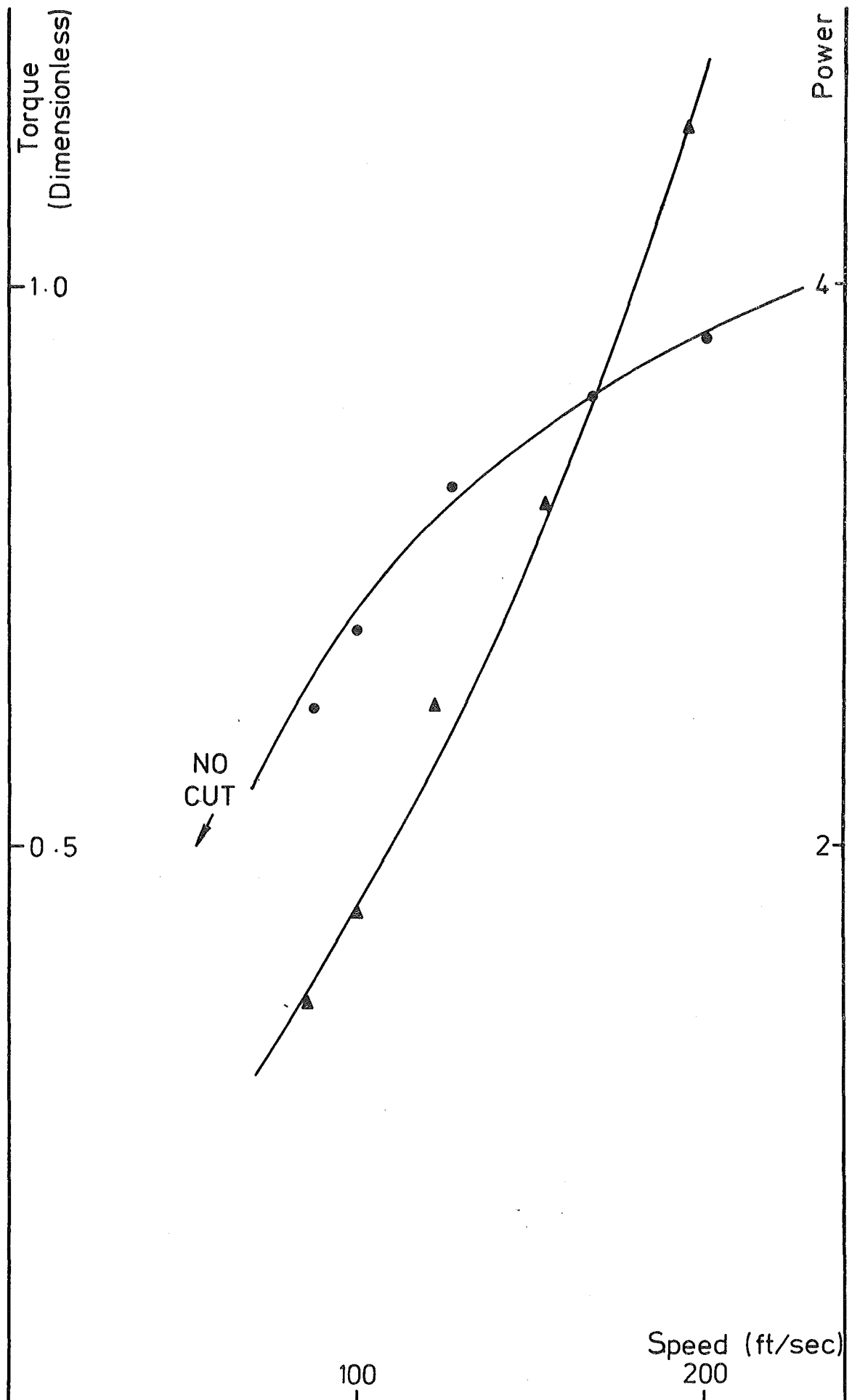


Fig 4 POWER/TORQUE vs SPEED, 1" WIDE STRIP

A minimum edge speed for cutting at the desired feed-in speed was not known, but estimated at 150 feet per second. It seemed necessary then, to run any further machines at around 200 feet per second. It was estimated that four horsepower would drive a bandknife at this speed, while cutting.

It was noted that wool is an unusually hard and abrasive fibre to cut. This observation was confirmed by personnel in the textile industry who had experienced rapid wear of knife edges in fabric cutting machines. At this time investigations into the basic mechanisms of fibre cutting were being carried out, and this is described in Chapter X.

II.7 DISCUSSION

The tests on this machine left many questions on wool cutting unanswered. However, it was considered that enough basic information was to hand to build a small bandknife machine. In summary, it was evident that :

- (a) a cutting speed of 200 feet per second was necessary;
- (b) a method of frequently sharpening the blade was essential;
- (c) a power requirement for a full size machine was estimated at four horsepower.

Consequently, it was decided to investigate ideas on holding the woolly skin before and during cutting, and then to combine the results of that work with the deductions from this machine to build a skin-shearing machine. Further investigation of bandknife cutting phenomena (wear rates, edge profile, etc.) was dependent on having a machine capable of continuous operation.

CHAPTER III

WOOL SIDE LOCATION

III.1 GENERAL DISCUSSION

The pelt is seldom of uniform thickness. Even if all the fatty matter is removed from the flesh side, there is still a variation in thickness from one area to another. The maximum thickness generally occurs around the neck and shoulders, and the minimum is found in the flank areas, particularly under the legs.

Because of this, it is impossible to obtain a plane surface on the wool side by locating the flesh side on the plane. If a cutting device which can only operate in one plane, such as a bandknife, is used, then it is desirable to have the wool side surface also in one plane.

Two possible schemes were considered. One of these was holding by introducing a number of horizontal wires into the spaces between the wool, which would tend to flatten the skin, particularly if a flexible support system were used to hold the flesh side. The other idea was to push a network of spikes into the wool, to press down on the skin. The development of this system is described in this Chapter, section 5.

III.2 PROPOSED SYSTEM

A line diagram of a cutting system using wool side, tensioned wire, location is shown in Figure 5. A conveyor belt (A), carried the skins, flesh side down to a bank of combs (B), which parted the wool. Running around pulleys (C), were the tensioned wires (D). These ran through tunnels

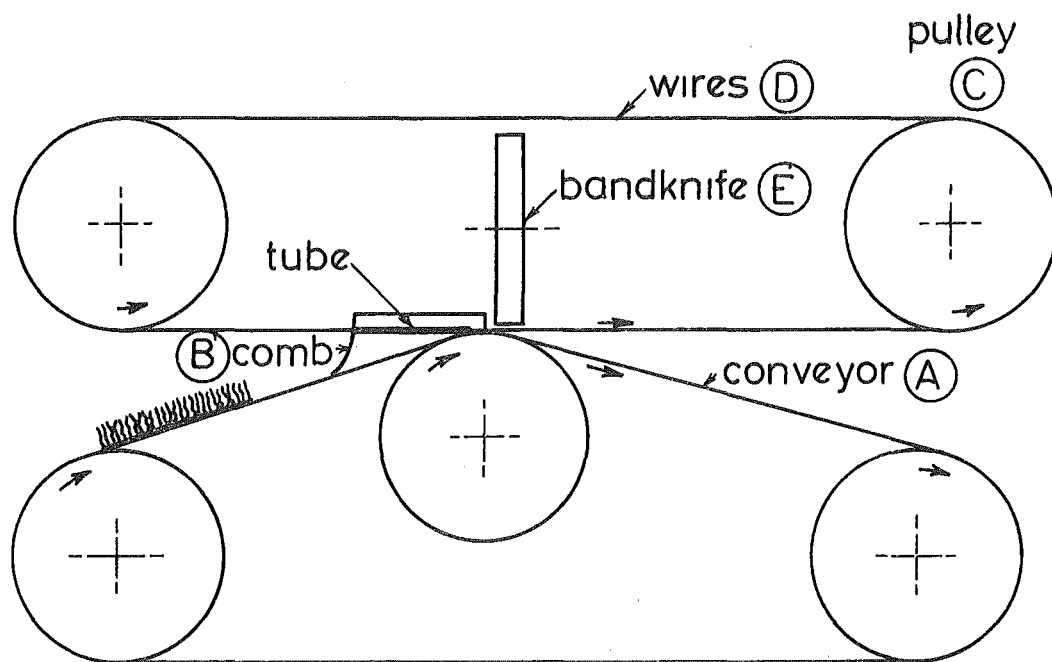


Fig 5 SUGGESTED COMB AND WIRE SYSTEM

in the combs, and were laid on the skin after the combs had parted the wool. It was expected that these wires would run at the same speed as the feed-in conveyor. While the skin was being levelled and held, a bandknife (E) with its blade running across the wires, then cut the fibres. Hence the wires located and held the skin against the conveyor (which could have a flexible surface) and prevented the blade from damaging the skin.

Obviously, the success of the system depended on the ability of the combs to open up the fleece in straight lines, without leaving any fibres under the wires.

Therefore, it was decided that investigations into combing would be carried out before any machine, working on this principle, was designed.

III.3 THE INVESTIGATION

III.3.1 Apparatus and Method.

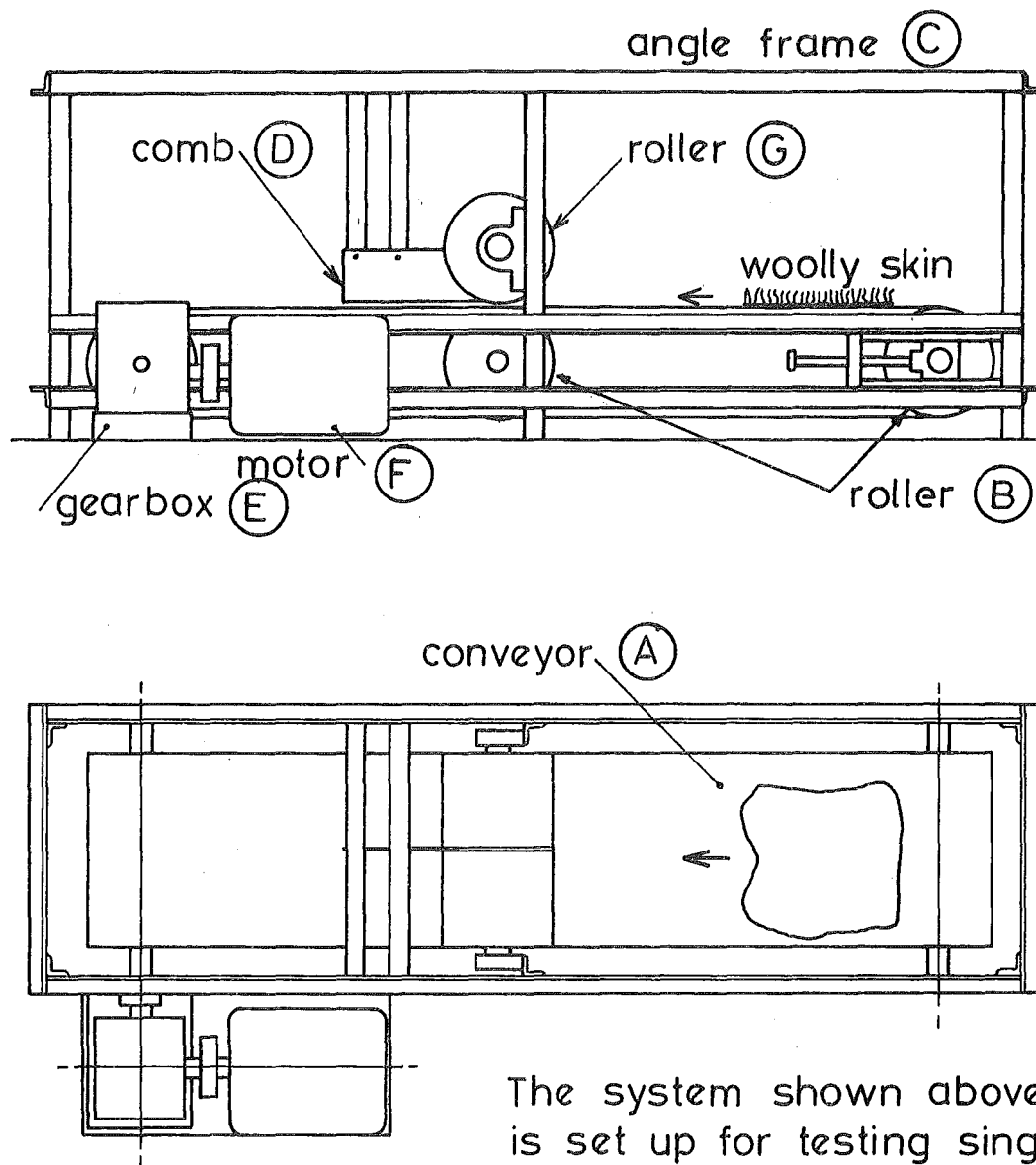
A conveyor, shown in Figure 6 was built. This was built using eighteen inch wide rollers (B) that were available at the time, and an eighteen inch wide conveyor belt (A) ran over these. The belt width was sufficient to take one half sheep-skin. The frame (C) had a number of support members for attaching comb banks (D). A one horsepower variable speed motor (F) driving through a reduction gearbox (E) powered the conveyor.

The belt speed was variable up to one foot per second.

III.3.2 Plain Combs.

Figure 7 shows the profiles of a number of combs used. These were made from sixteen gauge steel and were mounted in a row, one inch apart.

A number of problems were apparent :



The system shown above is set up for testing single comb and roller systems. Other combinations using the same frame were also used.

Fig. 6 COMB TESTING CONVEYOR

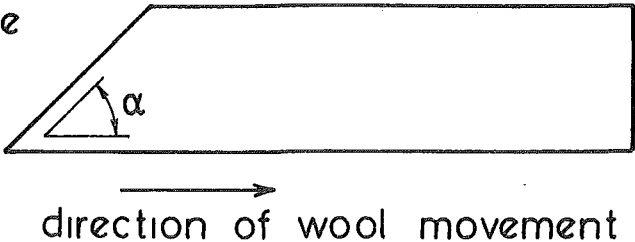
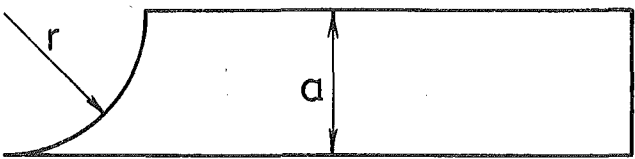
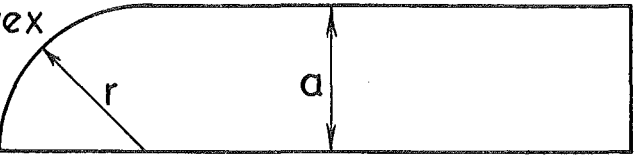
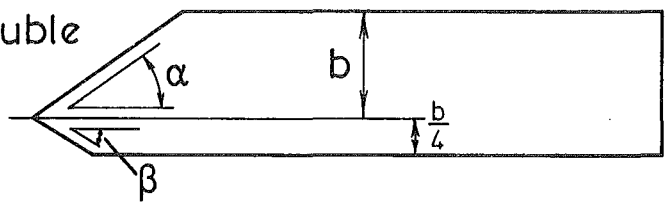
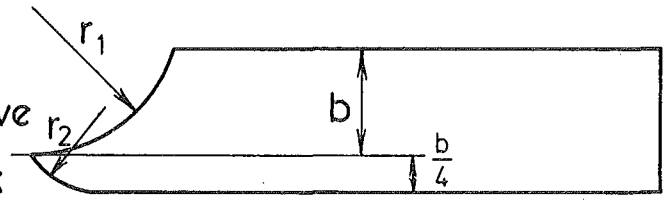
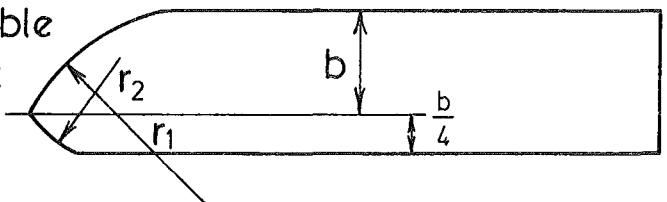
- (1) Plane  range of α values between 20° and 80°
- (2) Concave  radius & values between a and $3a$
- (3) Convex  radius & values between a and $3a$
- (4) Double plane  range of β from $\alpha/4$ to 2α
- (5) Concave
Convex  range of r_2 from $r_1/2$ to r_1
- (6) Double Convex  range of r_2 from $r_1/2$ to r_1

Fig 7 PLAIN COMBS

- (a) Entry to the leading edge area proved difficult. The skin tended to roll back, and jamming occurred.
- (b) On those occasions when the leading edge did not fold back, the combs jammed in the wool further along the skin. When this occurred, the skin slipped on the belt and moved no further.
- (c) Wool fibres tend to grow in groups. The most favourable parting line is consequently between groups, but the machine had no way of sensing where these areas were and, in any case, they are not necessarily arranged in lines.

Wool on a raw skin is often matted. This obviously increases the difficulties of parting.

From the tests it was apparent that a more positive drive system was needed to overcome the forces required to part the wool. A qualitative judgment indicated that the sharp profile combs, such as (2) in Figure 7 performed better than those with a less extreme taper, like (3) in Figure 7.

III.3.3 COMBS WITH MECHANICAL ASSISTANCE

It was decided that combing could possibly be achieved while the skin was being rolled between the centre conveyor roller and a further driven roller above this. The upper roller (1) in Figure 8, was slotted and the combs (2) ran in the slots. The conveyor (3) remained unchanged.

Referring to Figure 8, distance (b) is the clearance between the roller and belt, and (a) is the distance between the bottom of the comb and the underside of the roller. These were varied throughout the tests, by adjusting the roller

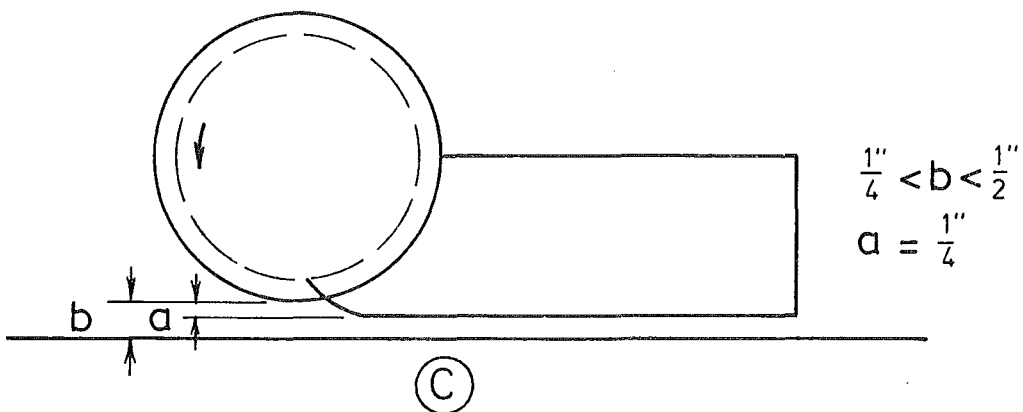
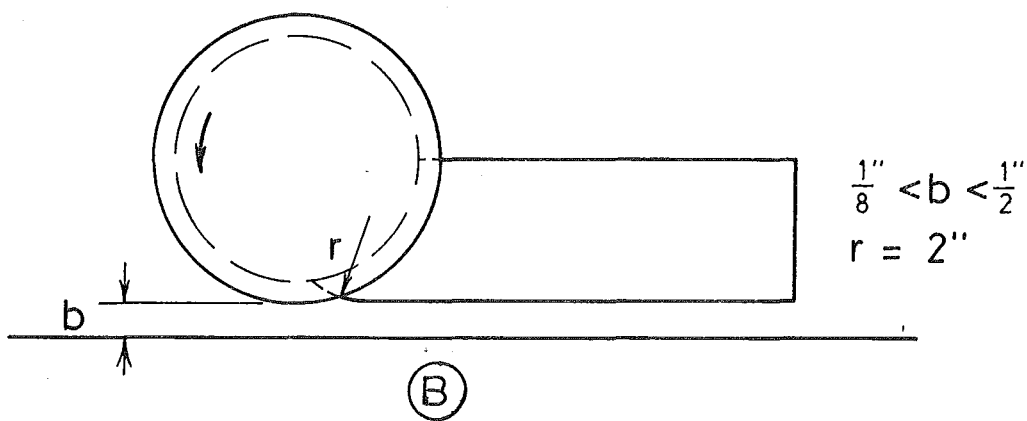
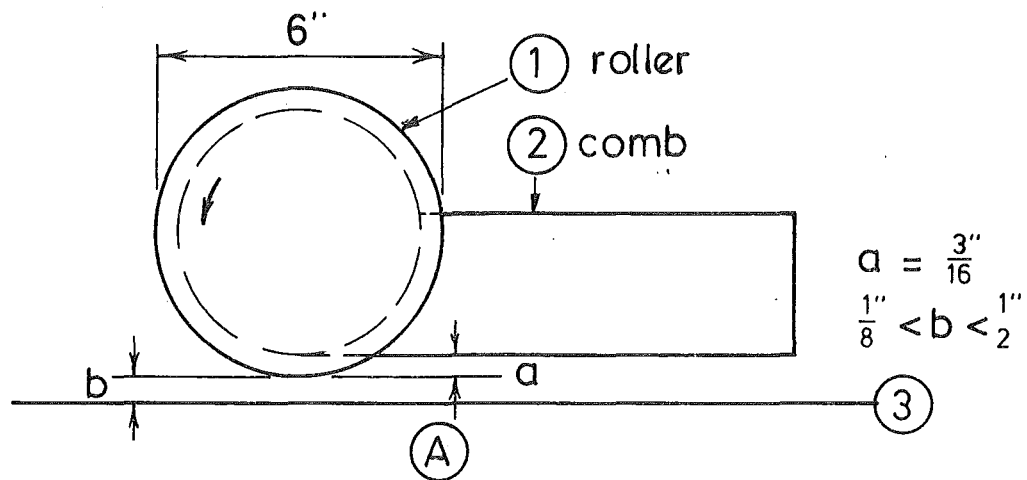


Fig 8 COMB AND WHEEL COMBINATIONS

position and making new combs.

The first tests were carried out with a value of $3/16$ " for (a) and the roller surface speed identical to the belt speed. Although the jamming problems no longer occurred, parting was not done to a satisfactory depth. As (b) was decreased, the parting improved, but the forces needed to move the skin under the roller increased.

Other comb profiles with different values of (a) were tried. These are also shown in Figure 8. Combs with profiles such as (B) in Figure 8 provided the best parting, but jamming was still a problem.

When the combs projected below the roller, as in (C), Figure 8, better parting, but higher forces, and a tendency to jam were observed.

A disturbing feature of the combing was that on some matted skins, the forces required to drag the combs through the wool were sufficiently large to cause tearing of the pelt.

It was concluded that plain combs, with or without rollers, were not practical means of parting wool on raw sheepskins.

III.4 COMBS WITH AIR JETS

It was expected that an air jet could part wool in a similar manner to a steel comb, and that if a jet was to be used to part the wool ahead of a comb, the forces needed to drive the skin under the comb could be reduced.

The comb shown in Figure 9 was constructed. The profile was that of the previously most successful plain comb, and a

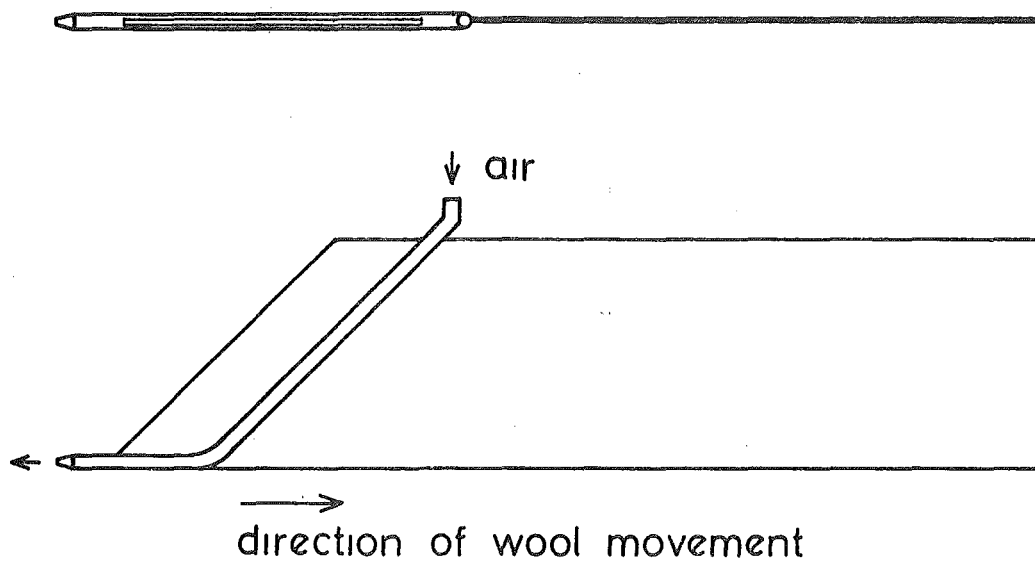


Fig 9 AIR JET COMB

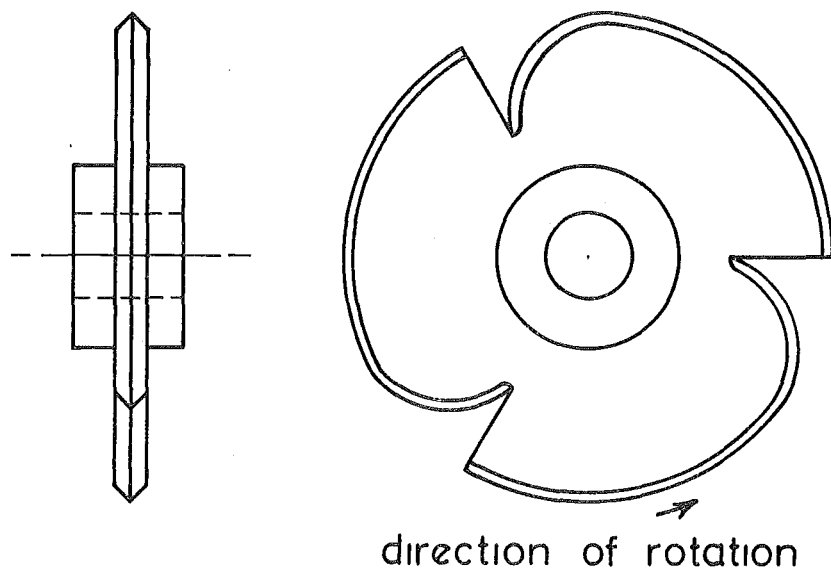


Fig 10 COMB WHEEL

passage fed air from a union on the trailing edge to a nozzle at the point. Air from a 100 p.s.i. line was discharged through the jet.

Although the force needed to drive the woolly skin past the comb was reduced, there was still a tendency for jamming to occur, and for the leading edge to be caught.

Different comb profiles and jet angles were tried with substantially the same result.

III.5 ROTARY COMB WHEEL

In an attempt to introduce a comb to the wool at a different speed to belt speed, a rotary comb wheel was built.

The wheel, Figure 10, was a $\frac{1}{2}$ " thick steel disc, one foot in diameter. Around the diameter there were a number of wedge shaped serrations. These tapered to a point along the leading edge. As the woolly skin passed under the wheel, it was driven at various speeds relative to the feed speed, from about three times faster in the same direction to three times the speed in the opposite sense. This was followed by a comb to maintain the parting made.

This system also proved unsatisfactory, because of inadequate penetration and jamming.

III.6 CONCLUSIONS

As none of the combing devices which had been tested proved capable of parting reliably, the concept of wire location, which depended on efficient combing for its success, was abandoned.

III.7 SPIKE PENETRATION

A simple experiment conducted with a flat plate with spikes protruding demonstrated that, if spikes with their points in one plane are pushed into the wool side of a skin resting on a resilient surface, there was a significant levelling effect. There was little sign of crushing of the fibres. (See Figure 11).

An important observation was that the levelling effect was noticeable some distance from a row of spikes. Clearly this effect was reduced as the distance increased, but it was observed that, up to about one inch distance, the variation in vertical position was of the order of one eighth of an inch or less, depending on the vertical force.

It was clear that a spike system could be used to level the skin and prevent movement during cutting, provided the spikes could be retracted before reaching the blade.

A system of continuously introducing spikes and retracting them was devised and as this was incorporated in a complete cutting machine, it is described in the following chapter.

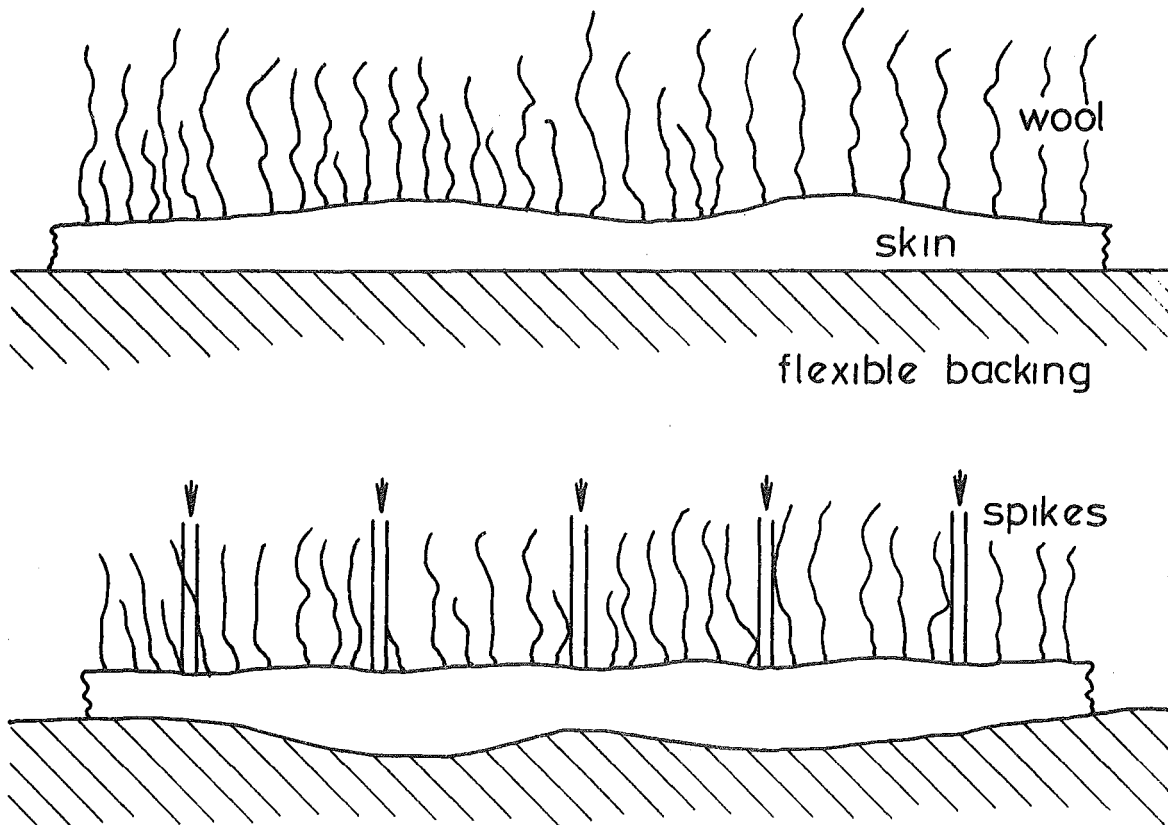


Fig 11 EFFECT OF SPIKES

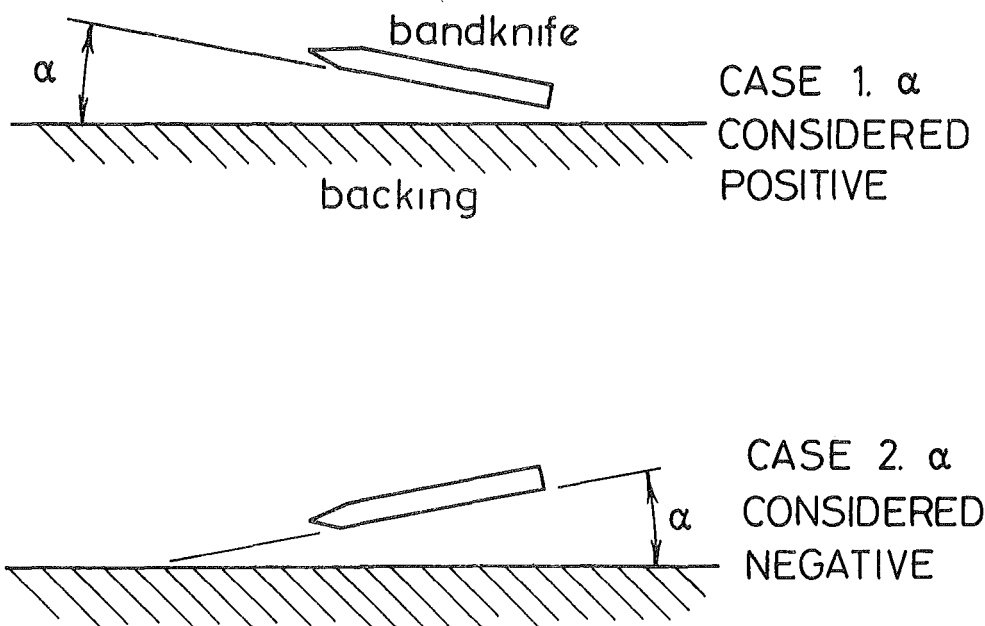


Fig 12 BANDKNIFE ANGLES

CHAPTER IV

THE EXPERIMENTAL SKIN SHEARING MACHINES. 1

IV.1 DISCUSSION

It was decided to build an experimental machine using the knowledge already gained from the disc cutting experiments and the combing tests. There were three reasons for this decision :-

- (a) A machine which worked reliably was needed to investigate the wool cutting process.
- (b) One of the objectives of the project was to attempt to produce a working machine.
- (c) The earlier work had shown that the best way to investigate proposed handling systems, such as the spike penetration system, was to try them. Naturally, it was essential that the ideas be given every change of working: that is, adequate supporting systems, and a high standard of construction, were necessary, because in an investigation of this type, the maintenance of small clearances etc. can be essential for successful performance.

Furthermore, experience with the disc cutter had indicated the disadvantages of models. These invariably have some scale effects.

However, as the machine was to be an experimental shearing rig, a test bed for ideas, it was not necessary that it be built to prototype dimensions. For this reason, the feed-in conveyor was the conveyor used in the combing experiments, with suitable modifications.

IV.2 DESCRIPTION OF THE MACHINE

IV.2.1 General Description.

A diagrammatic representation of the machine is shown in Figure 13.

Spike introduction and retraction from the skin was achieved by using a rubber conveyor belt with protruding spikes (A), converging with a foam rubber covered feed-in conveyor (B), from which it diverged as it passed around an end roller (C), before reaching the bandknife blade (D).

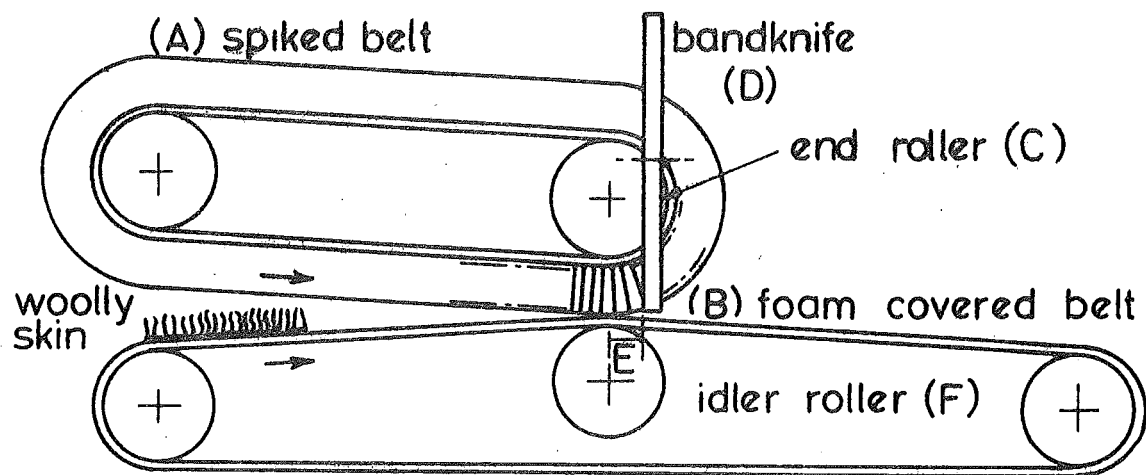
At this stage no provision was made for the collection of the cut wool, and these were expected to be carried out of the cutting area by the continuation of the feed-in belt.

IV.2.2 Details of the Skin Handling System.

The spiked belt was made from a three-ply rubber conveyor belt, and some 1500 two inch nails were driven through it. A jig was used for spacing the spikes at three quarters of an inch between adjacent rows and files. Following this process the points of the nails were ground so that they were in one plane. The ground ends were then heated with a welding torch to remove any grinding burrs.

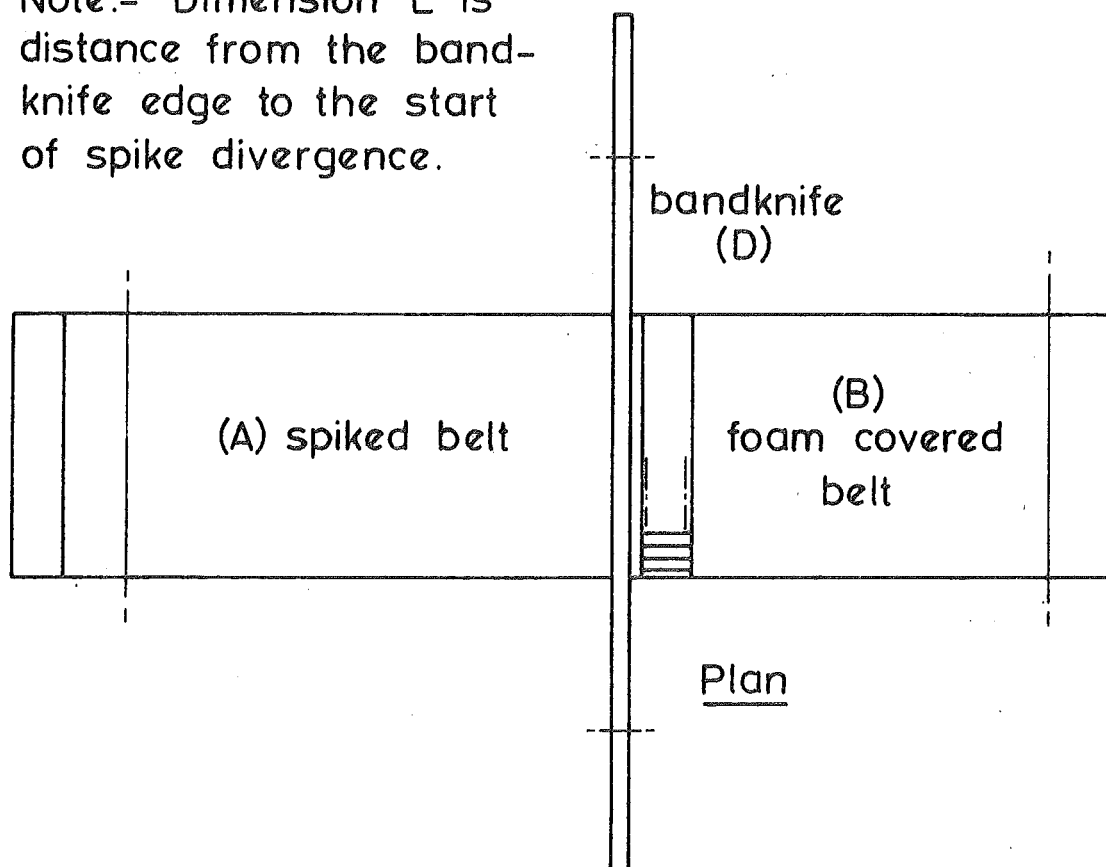
The feed-in belt was the two-ply rubber belt used in combing experiments, with a covering of one half inch thick foam rubber. An idler roller (F) supported this belt at a point directly below the drive roller of the spiked belt.

The woolly skin was laid on the lower belt, wool side upwards. Spike penetration occurred as the two belts converged, and retraction occurred as the spiked belt moved up and



Elevation

Note:- Dimension E is distance from the bandknife edge to the start of spike divergence.



Plan

Fig 13 DIAGRAMATIC REPRESENTATION OF SPIKED BELT SHEARING MACHINE.

around its drive roller.

The bandknife blade was positioned as closely as possible to the point of divergence of the spiked belt and the upper skin surface, i.e. $\frac{1}{4}$ " to $\frac{1}{2}$ " above the lower belt and $\frac{1}{8}$ " clear of the spike tips (see Figure 13).

A one horsepower variable speed motor, driving through a fifteen to one reduction gearbox, powered both belts. An adjustable diameter pulley, in the spiked belt drive line, allowed synchronisation of the surface speeds of the two belts.

IV.2.3 Details of the Bandknife.

After consideration had been given to the three possible methods of obtaining a bandknife :

- (a) by buying a commercially built bandknife;
- (b) by modifying a bandknife built for another purpose;
- (c) by building a bandknife;

it was decided to modify a used bandknife. Buying a new, commercially built machine was expensive, and building a complete machine was time consuming.

Modifications were carried out on an upright, fabric cutting bandknife machine. This machine, a Kuris ZBM 58 had a blade sharpening system; and replacement blades, and grinding wheels, were readily obtainable from a local agent.

A number of modifications were made to the machine. The cutting table and stand were discarded, and support structures to carry the bandknife in a horizontal position were made. These structures (details of which may be found in the modification drawings, Ap.VIII) incorporated an adjust-

ment whereby the bandknife could be rotated about an axis through the working length of the blade, allowing the angle between the blade and the horizontal plane to be varied up to fifteen degrees in either direction. (See also Figure 12).

The frame of the bandknife, which was of cast iron, was cut midway between the wheels, and a fourteen inch long spacing piece inserted. This spacer included a housing for the grinding wheels which had been mounted on the working side of the machine previously. This modification increased the working length of the bandknife, but necessitated the welding in of extra blade length.

The blade sharpening system was not modified. This consisted of two three inch diameter grinding wheels, which were arranged to be turned by the blade while grinding it. (Refer to Chapter VIII and Figure 46).

As the original blade speed was ninety feet per second (5400 feet per minute), a new drive system was constructed to increase the speed to 220 feet per second. A new drive wheel shaft and bearing housing replaced the original system of supporting the drive wheel on the motor shaft. A five horsepower, 2850 r.p.m. motor replaced the one horsepower, 1410 r.p.m. unit. Drive to the wheel shaft was by vee belts, permitting speed alteration by pulley size changes.

When the bandknife was installed in the machine, adjustment of the clearance between the blade and the feed-in belt was altered by moving the idler roller in the lower belt up and down.

IV.3 TEST RUNS

IV.3.1 Experimental Conditions.

Initially the blade clearance was set at one half of an inch, and the point of divergence of the paths of the spike tips and the lower conveyor was then one inch distant from the blade edge.

The feed-in speed was set to one foot per second. The blade was sharpened with equal angles above and below the centreline. Initially, the blade was parallel to the lower belt.

Woolly skins from crossbred sheep were used in the tests. Quarter skin samples, with wool lengths varying from two to four inches, were fed in to the machine. The blade was re-sharpened between each run.

During the tests the blade clearance and angle were altered, and different feed-in speeds were tried.

A number of problems were evident. These could be divided into problems with the bandknife, and problems with the holding system.

IV.3.2 Performance of the Bandknife.

No problems were experienced with the unloaded running of the bandknife, following the modifications. The blade tracking and sharpening were both satisfactory, and the higher speed did not significantly increase vibration in the frame.

When the bandknife was working as part of the machine, two factors were apparent :-

- (a) provided the blade was sharpened frequently, the cutting of the wool fibres was readily achieved, at the feed-in speeds required;
- (b) on those skins which were shorn without damage (refer to the next section), a gradual increase in stubble length from the leading edge of the skin to the rear was noticed. It was thought that the blade was either twisting or bending upwards, or both, under the loads imposed by cutting.

The angle between the blade and the lower belt was altered to attempt to compensate for this. When the blade edge was inclined downwards relative to the incoming belt the opposite effect of reduced stubble length, and ultimately pelt damage, occurred.

An upward inclination increased the stubble length effect. As the phenomenon appeared to have no point of neutral equilibrium, it was decided to modify the bandknife by providing a system of restraining the blade. This is described in section IV .4 - Modifications to the Machine.

IV.3.3 Performance of the Handling System.

The spiked belt holding system did not perform acceptably. Although the spikes provided a levelling and holding action which allowed the blade to sever the wool fibres close to the pelt, there was a tendency for the skin to be lifted by the spikes as they diverged from the belt. This resulted in damage to the skin, because the blade cut through the raised pelt.

The tips of the spikes follow a longer path than those at the belt end and as the spiked belt lifts from the lower belt by passing around the drive roller, the spikes diverge. This divergence effect was causing the spikes to grip any matted areas, and thus lift the skin clear of the lower belt.

On short woolled, unmatted skins other effects were noticed. The anticipated difficulty of introducing the leading edge to the blade without folding the skin back did not eventuate. However, some wool was left uncut on that side of the skin that the blade was moving toward. This was a narrow band of fibres, evidently bent over, as they had no support from adjacent fibres. The amount of wool left was not sufficient to cause concern at this stage, because other problems were more evident.

It was decided to modify the handling system in an attempt to overcome the lifting problem.

IV.4 MODIFICATIONS TO THE MACHINE

IV.4.1. Modifications to the Bandknife.

One modification was made to the bandknife. This was the installation of rollers above and below the blade at each side of the working area. These were mounted on frames which were clamped together to grip the blade (Figure 14). This modification reduced the free length of blade by thirty per cent, and was intended to reduce the tendency to twist or bend. The resistance to bending of a uniformly loaded beam is proportional to (free length)⁴ and for twisting is proportional to the free length.

IV.4.2 Modifications to the Skin Handling Systems

Two modifications were made in order to prevent the

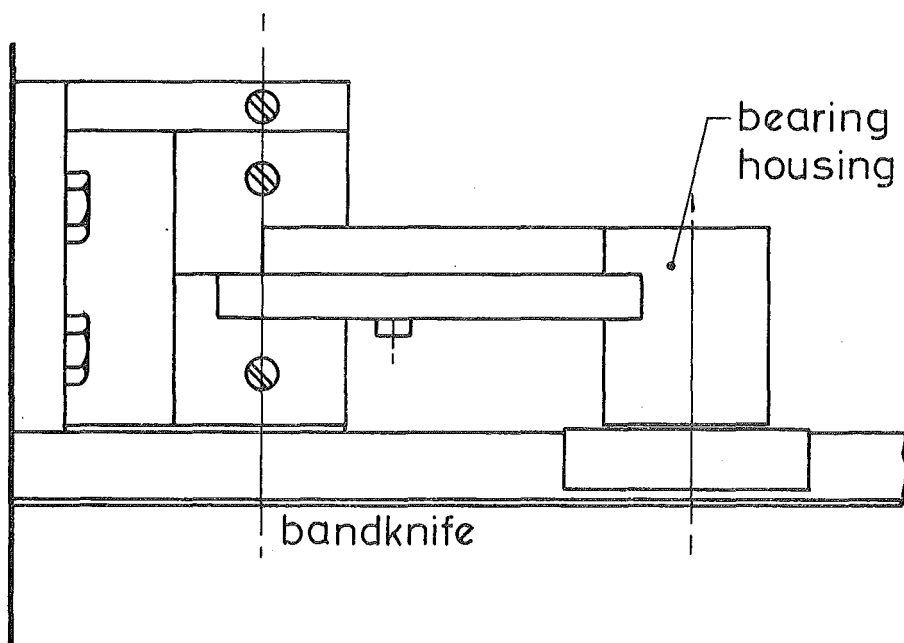
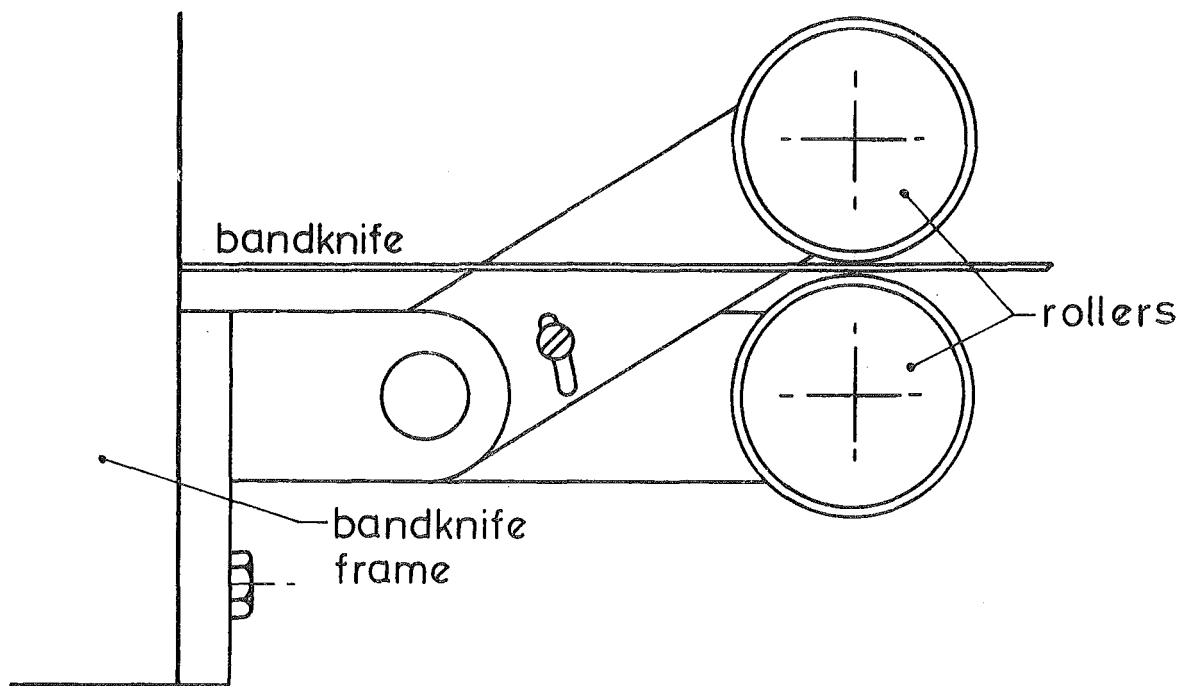


Fig 14 BANDKNIFE RESTRAINING UNITS

lifting of the skin by the spiked belt.

- (a) The modified machine is shown in Figure 15.

The position of the upper belt relative to the lower belt was altered. The idler roller in the lower belt was raised to a height of three inches above the end rollers; the lower belt then traced a triangular path. Both penetration and retraction of the spikes was then achieved by convergence and divergence of linear portions of the belts. Spikes then did not diverge as before, during retraction.

- (b) A slotted plate (Figure 17) was mounted in front of the drive roller of the spiked conveyor. The spikes moved through the slots, and the parts of the plate between the slots were intended to push down any wool which was carried by the spiked belt.

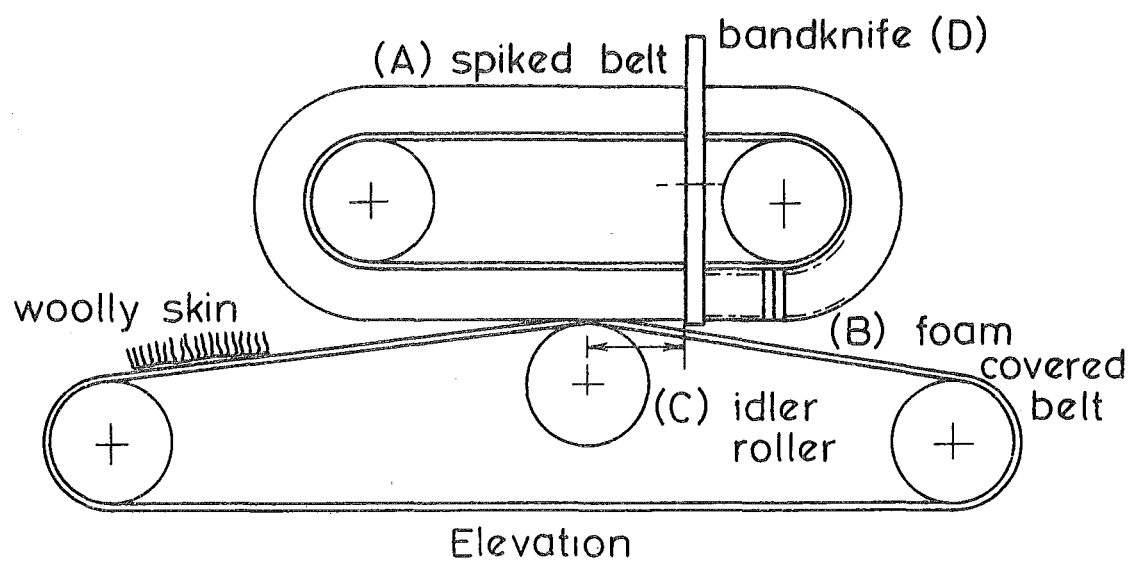
IV.5 RESULTS OF MODIFICATIONS

IV.5.1 Results of Modifications to the Bandknife.

The problem of increase or decrease of stubble length, noted in IV.3.2, was reduced, but not eliminated. As this problem did not greatly affect the machine performance, further modifications were not done immediately. However, a slot type guide along the entire working length of the blade was built later, and Chapter VI has an account of blade guide investigations.

IV.5.2 Results of Modifications to the Handling System.

The problem of skin lifting was still evident despite the modified belts. Although the tendency for the skin to be



Note increase in dimension
(E) compared to that of
figure 13

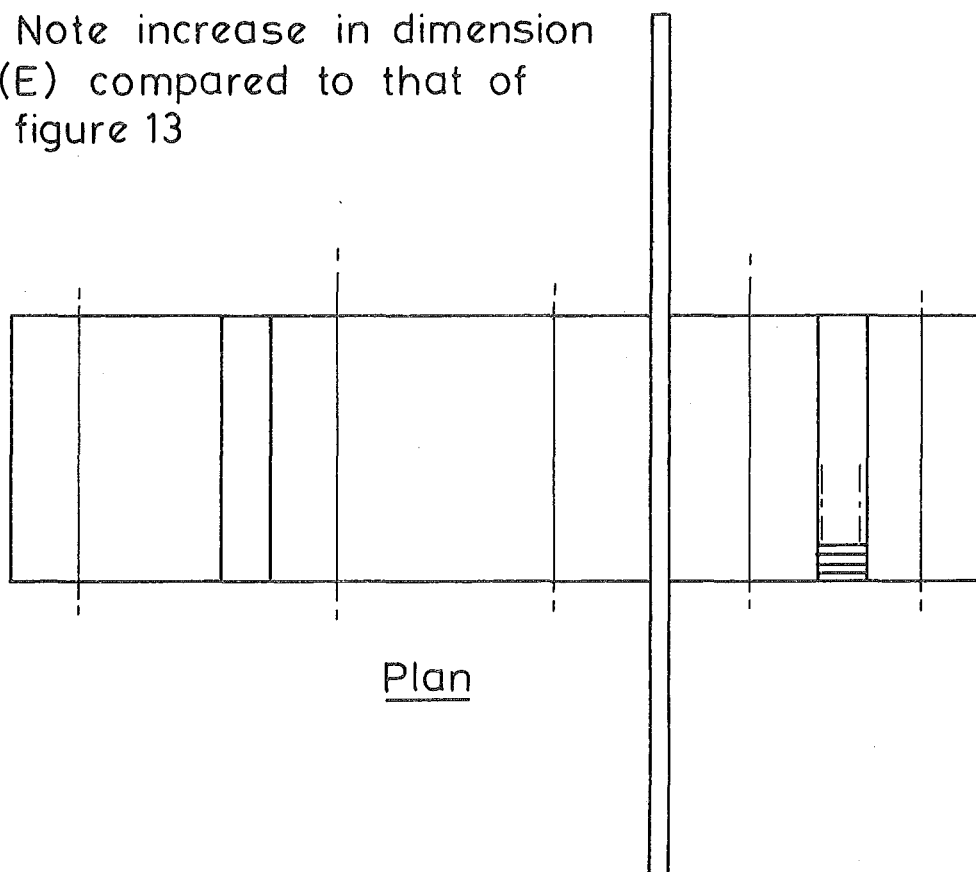
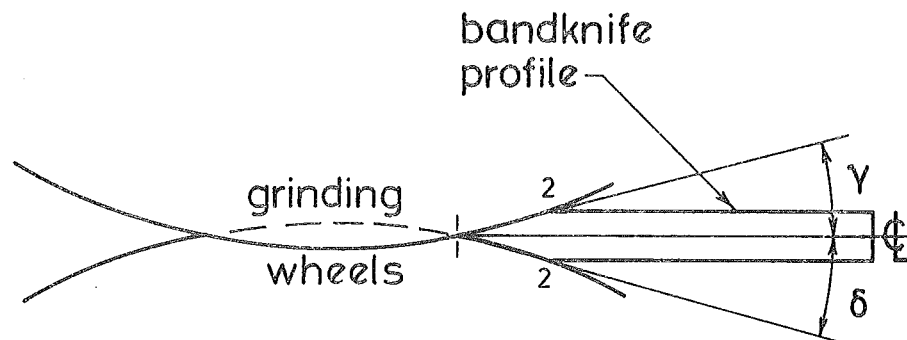


Fig 15 DIAGRAMATIC REPRESENTATION OF MODIFIED
SPIKED BELT SHEARING MACHINE



During machine testing
bandknife grinding angles
 γ and δ were kept equal.

Fig 16 BANDKNIFE GRINDING ANGLES

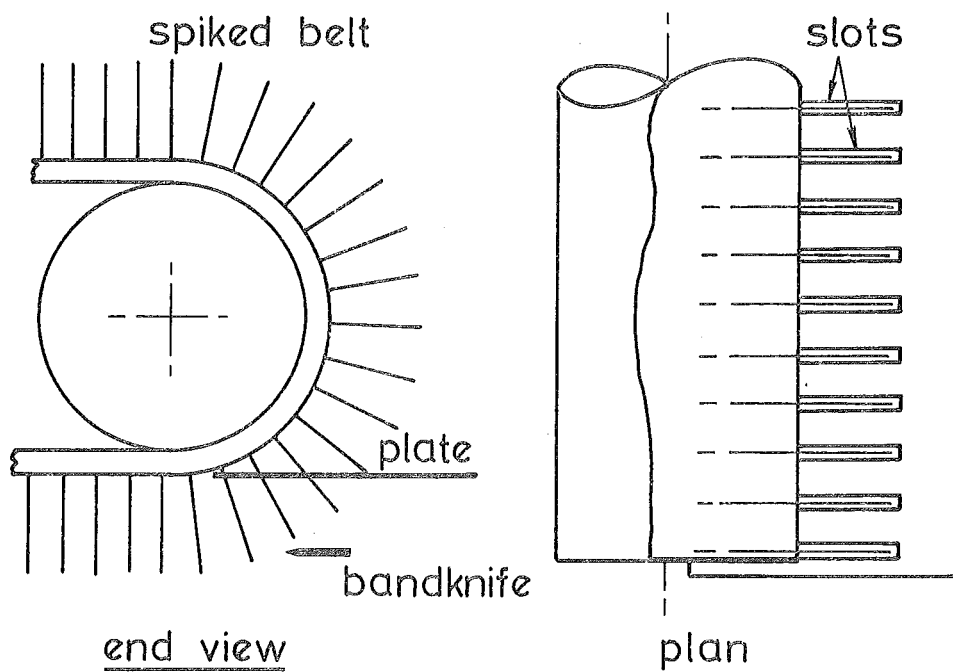


Fig 17 WOOL GUIDES

lifted was decreased, it was not absent. Further, the less rapid divergence pattern resulted in less holding and levelling effect because the blade was, of necessity, further from the point of divergence.

Again, combinations of clearances, and even a variation in relative speed, were tried, but the system was still not satisfactory.

The slotted plate rapidly accumulated a build-up of wool fibres in the slots, and jammed.

IV.6 DISCUSSION

It was considered that there were two possible means of improving the action of the spike penetration holding system:

- (a) Either of the two systems already tested could be used in conjunction with a system of holding the skin against the lower belt, to resist the upward forces; or
- (b) another system of spike retraction, designed to avoid lifting the skin could be devised.

Considering the former possibility, it was clear that it was difficult to provide a means of holding the skin onto the lower belt, while maintaining a resilient backing. The use of suction, which was a possibility, was not compatible with resilient backing because the compression effect would result in the surrounding material being cut. If a rigid backing was to be used, the ability of the spikes to push the irregularities out would be greatly reduced.

It was also noted that the necessary distance between the blade edge and the spikes was greater than desirable, for optimum holding.

The second possibility, of devising a new spike system, was adopted. It was decided that a positive retraction spike system would be investigated. The development of this system and the modified machines it was used in is described in the next chapter.

CHAPTER V

THE EXPERIMENTAL SKIN SHEARING MACHINES 2

V.1 GENERAL DISCUSSION

Experiments performed with retraction of spikes from small woolly skin samples suggested that the wool was less likely to follow the spikes upward if:

- a) The direction of motion of the spikes was at right angles to the plane of the skin, and
- b) The movement of the spikes was rapid.

These results suggested that a sudden, vertical retraction of the spikes was desired.

Achieving such a motion with the spiked belt would have been difficult. A new spike system was built.

V.2 THE CAM OPERATED SPIKE RETRACTION ROLLER

A roller which had rows of retracting spikes around its circumference was built. Because the movement of the spikes was controlled by cams, this roller became known as the cam operated roller, and in the interests of brevity, will be referred to in this thesis as the C.O.R.

The C.O.R. is drawn in Figure 18. A six inch diameter eighteen inches long, cast iron bar (A) had six evenly spaced radial slots milled along its length. Rectangular bars (B) of slightly greater length than the roller were placed in the slots, with an equal length of bar protruding from each end of the slots. These bars could then slide in the radial direction, but the slot restrained their circumferential movement,

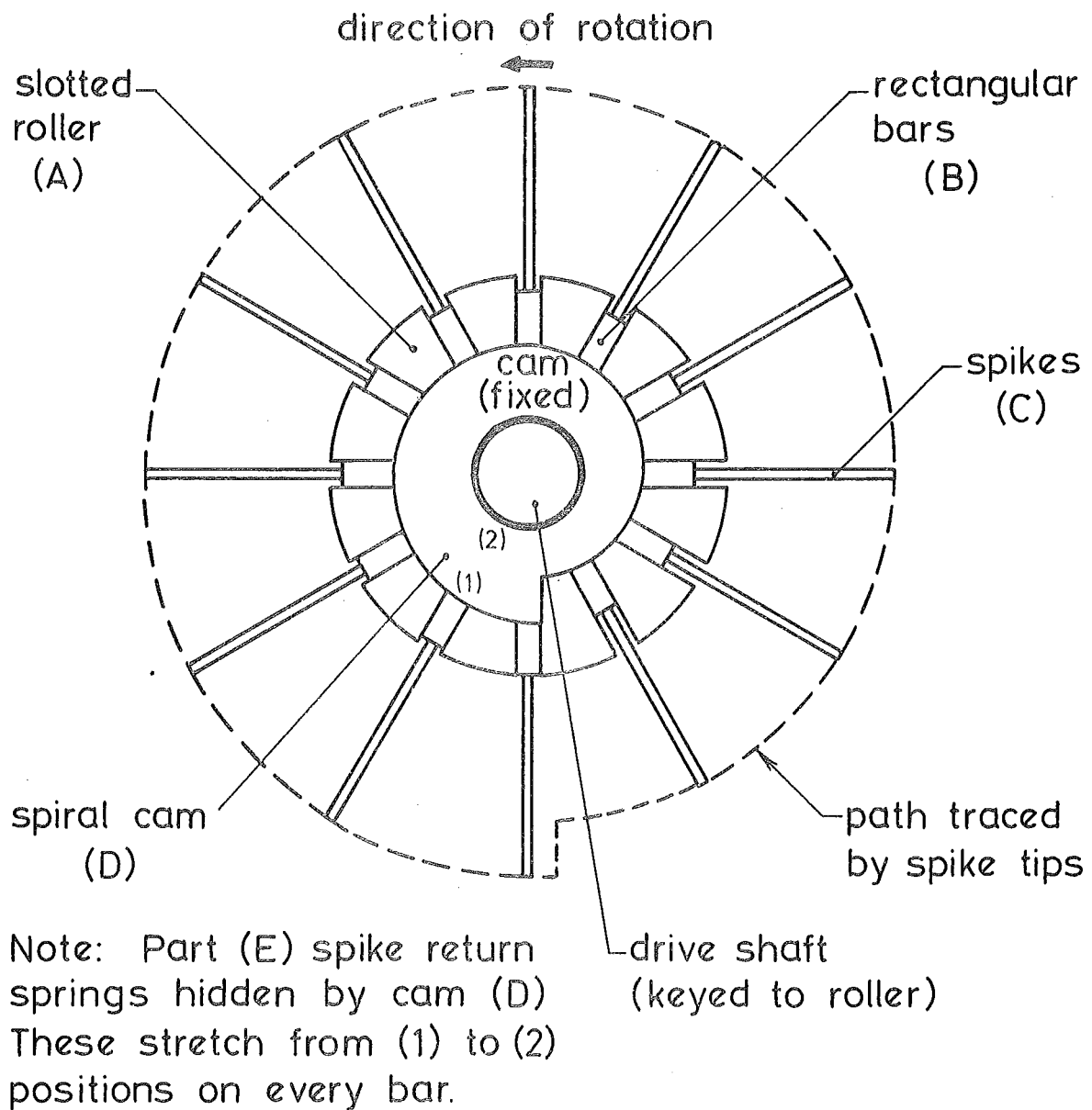


Fig 18 END VIEW OF CAM OPERATED ROLLER

and axial movement was prevented by locating pins.

Each bar had eighteen, two inch long spikes (C) protruding from its outer edge. These spikes thus projected from the roller and, as they were attached to the bars, could only move radially.

The ends of the bars rested on two spiral cams of identical shape (D). These cams had a gradual ramp over most of the circumference, followed by an abrupt step to the minimum diameter at a point following the point of maximum throw. See Figure 20.

The bars were kept in contact with the cam by springs (E) in Figure 18. The cams remained stationary and the roller rotated, moving the bar projections over the cam profiles. The roller rotated in a direction such that the bars moved around the cam from minimum to maximum diameter. At the step, the springs rapidly pulled the bars down on the lower part of the cam.

The path then traced by the spikes was similar to the cam profile but there was an inevitable small inertia lag at the step.

V.3 THE MACHINE

Figure 19 shows a diagrammatic representation of the machine incorporating the C.O.R. The C.O.R. (A) was mounted over the foam covered belt (B) in such a way that the spikes were converging with the belt as they approached the point of maximum throw on the cam. The cams were positioned with the steps at the point where the lower belt was the minimum distance from the C.O.R.

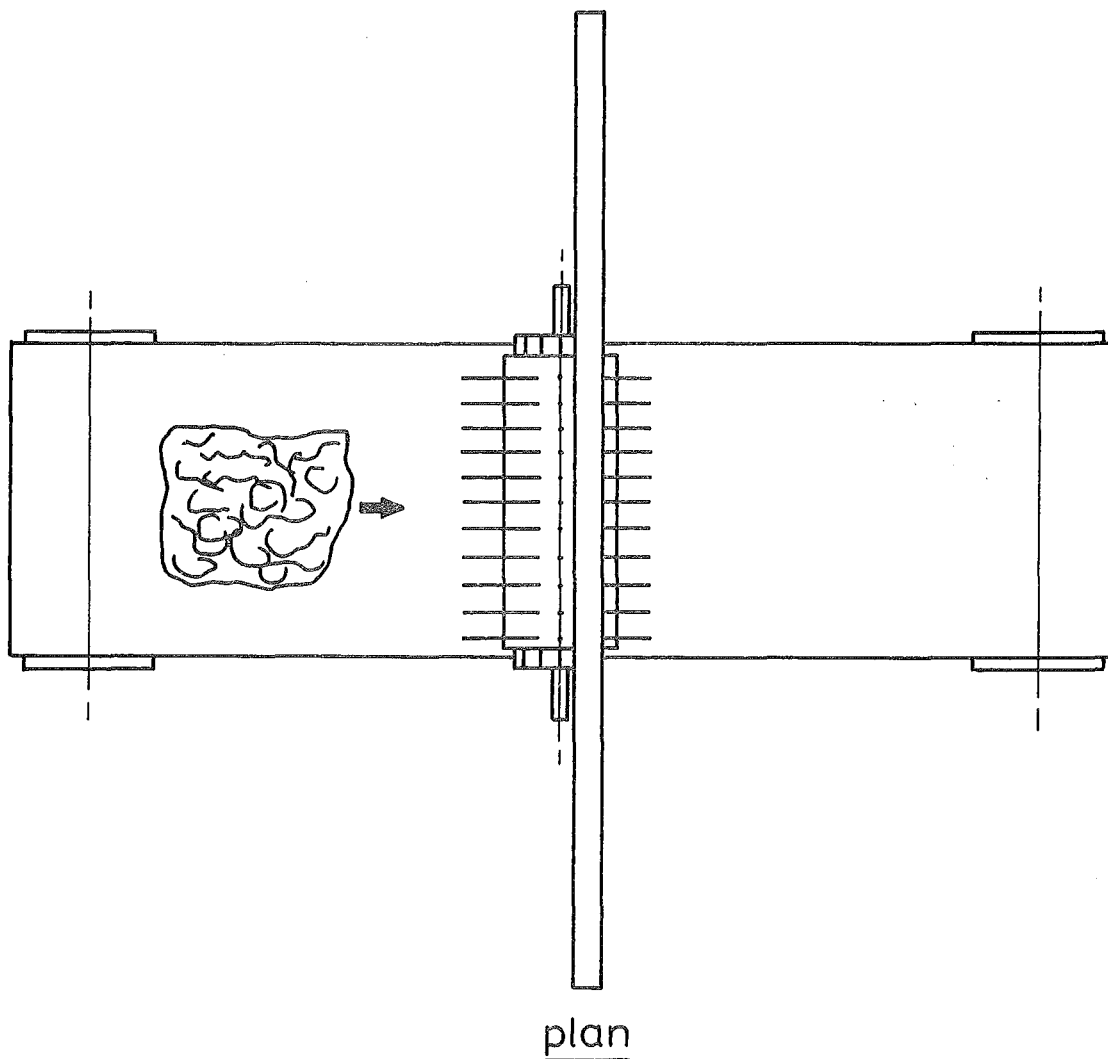
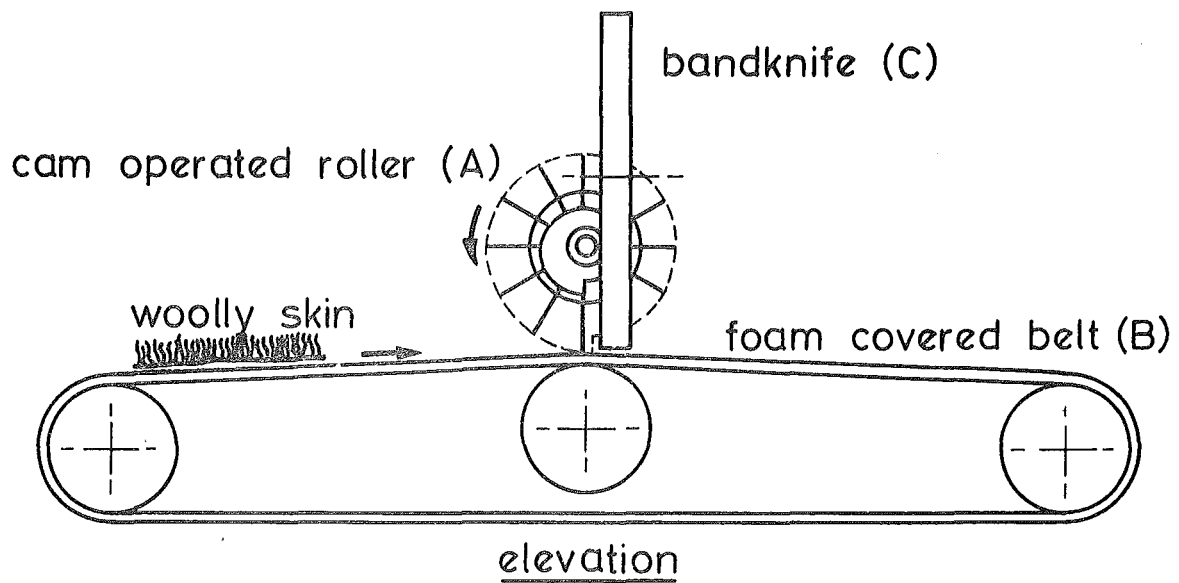


Fig 19 DIAGRAMATIC REPRESENTATION OF CAM
OPERATED ROLLER SHEARING MACHINE

The bandknife (C) was mounted with its blade above the foam belt and a short distance past the point of spike retraction.

The C.O.R. was driven from the same drive motor, gearbox and variable pulley that had powered the spiked belt system.

V.4 MACHINE TRIALS

The first runs were made to determine how close the blade could be placed to the spikes. It was found that it was necessary to position the forward edge of the blade three-eighths of an inch from the projection of the edge of the step, for the feed in speed of one foot per second. See Figure 20.

Woolly skin cutting tests showed that reliable cutting had not yet been achieved. The skin still tended to lift and the bandknife still cut into the skin on occasion.

Observation of the cutting process suggested that the combined effects of the cutting force and the stubble drag on the blade caused the skin to buckle below rows of spikes. A disadvantage of the C.O.R. system was the increase in distance between adjacent rows of spikes, compared to the spiked belt system. From tip to tip, the average circumferential distance from one row of spikes to the next was two and a quarter inches.

It was also noticed that the leading edge was not often damaged. When buckling of the skin and the resulting cutting of the pelt occurred it was often found near the trailing edge of the skin.

The clearances between blade and belt, belt and roller and roller and blade were all subjected to experimentation,

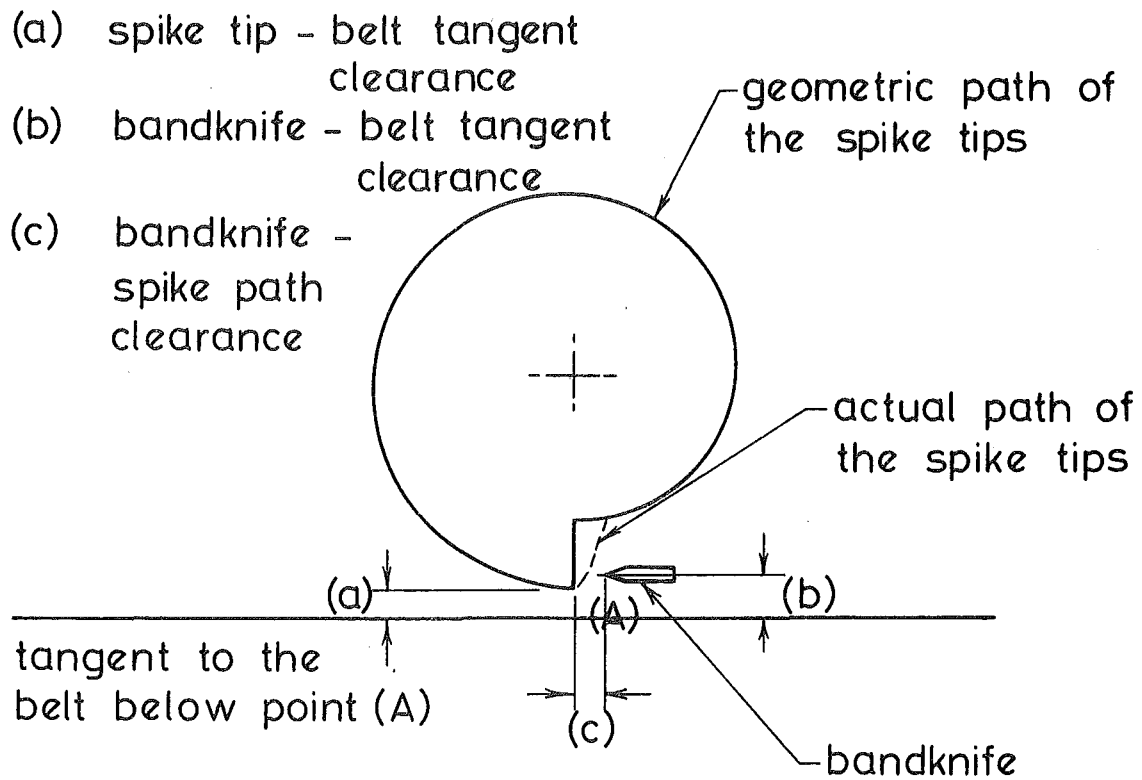


Fig 20. OPERATING CLEARANCES FOR C.O.R.

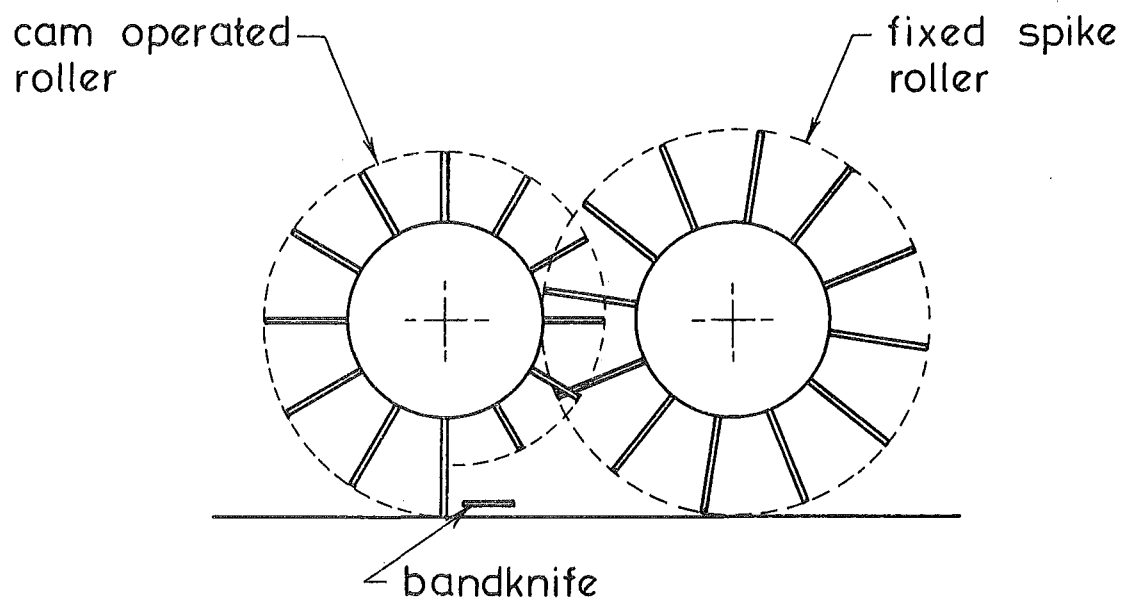


Fig 21 ARRANGEMENT OF FIXED SPIKE ROLLER

but these alterations did not change the overall pattern.

V.5 MODIFICATIONS TO THE MACHINE

Qualitative experiments carried out during the trials described above suggested that an application of vertical load to the shorn pelt, as it left the blade, had two effects:

- a) A levelling action under the blade was observed.
- b) The resistance of the incoming skin to buckling and folding was increased.

As a result of this, a fixed spike roller was arranged to run with its spikes intermeshing with the C.O.R. The roller, shown in Figure 21, then pressed down on the pelt after cutting and helped drive the skin through the machine. The roller dimensions were the same as those in the C.O.R. system but there was no retraction of the spikes.

V.6 RESULTS OF THE MODIFICATIONS

Further cutting trials showed that there was still not satisfactory holding. Despite the addition of the fixed spike roller, there was still a tendency for lifting of the skin and buckling.

The elasticity of the skin was apparently great enough to allow buckling to occur even when the leading edge was being held. The spikes themselves prevented any buckling from being removed by the friction of the knife on the stubble (in a similar manner to pushing a fold along a length of fabric) by stopping movement at that point.

V.7 DISCUSSION AND DECISIONS

It was clear that many of the problems arose from the intermittent nature of the holding system. Although levelling was still satisfactory, it was necessary to provide additional uniform holding of the skin.

Two possibilities were:

- a) A new retraction system with closely spaced spikes
- b) Additional holding from the feed-in system, combined with the existing C.O.R.

While there were feasible means of achieving the former possibility, it was thought that there was still the likelihood of lifting of the skin. In any case, all the possible systems would have been complex.

The latter suggestion had a number of advantages:

- a) Additional holding from a resilient backing would permit the continued use of the C.O.R. which had been shown to contribute to the levelling of the surface.
- b) Additional holding down force would have the advantage of both preventing lifting and increasing the resistance to sliding or folding of the skin.

During the time when a solution to the problem of holding the skin against a porous surface was being sought, an already developed system became available. Consequently a modified machine was constructed using this device.

V.8 THE EVANS ROLLER

V.8.1 Background A roller with a resilient backed, skin holding surface had been developed by Mr D. Evans of the Alliance Freezing Company, Invercargill, New Zealand. During

a visit to the plant the roller was demonstrated and offered to the project.

V.8.2 Principle of the Roller The roller, shown diagrammatically in Figure 22, consisted of four major elements. An eighteen inches wide by eighteen inches diameter steel roller (A) was carried in bearings (B). A four inches layer of foam rubber (C) covered the roller surface. A layer of canvas (D) was wrapped around this and eighteen gauge steel bands, half an inch wide (E), encircled the canvas. The bands were rivetted to form a row of loops laid edge to edge across the roller.

The holding effect was produced by a large number of punched projections in the bands. These were formed by punching from behind the band with a V-shaped punch, as shown in Figure 23. When these bands, with projections facing outwards, were moved over a woolly skin with the projections facing the flesh side, the skin attached itself to the bands. In practice, this movement was achieved by rotating the roller above a conveyor belt moving at a slightly greater speed than the conveyor. The roller then lifted the skin clear of the belt in a manner similar to the operation of wool drying suction rollers.

In addition, there was considerable resistance to sliding, folding and buckling of the skin.

Tests carried out by the New Zealand Leather and Shoe Research Association showed that no significant damage was done to the pelts that had been held on the Evans Roller.

V.8.3 The Roller in a Wool Shearing Machine The Evans Roller performed three tasks:

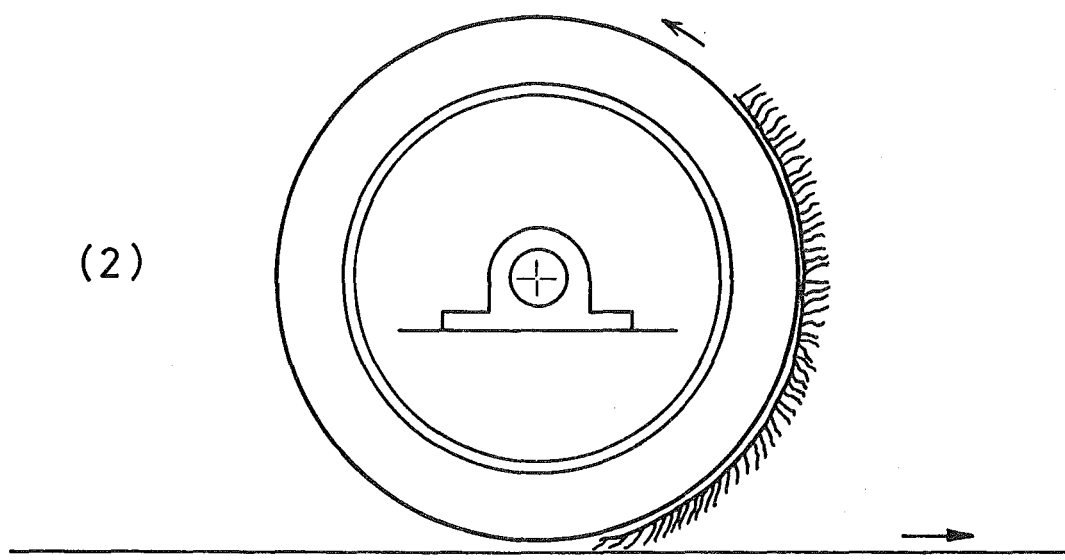
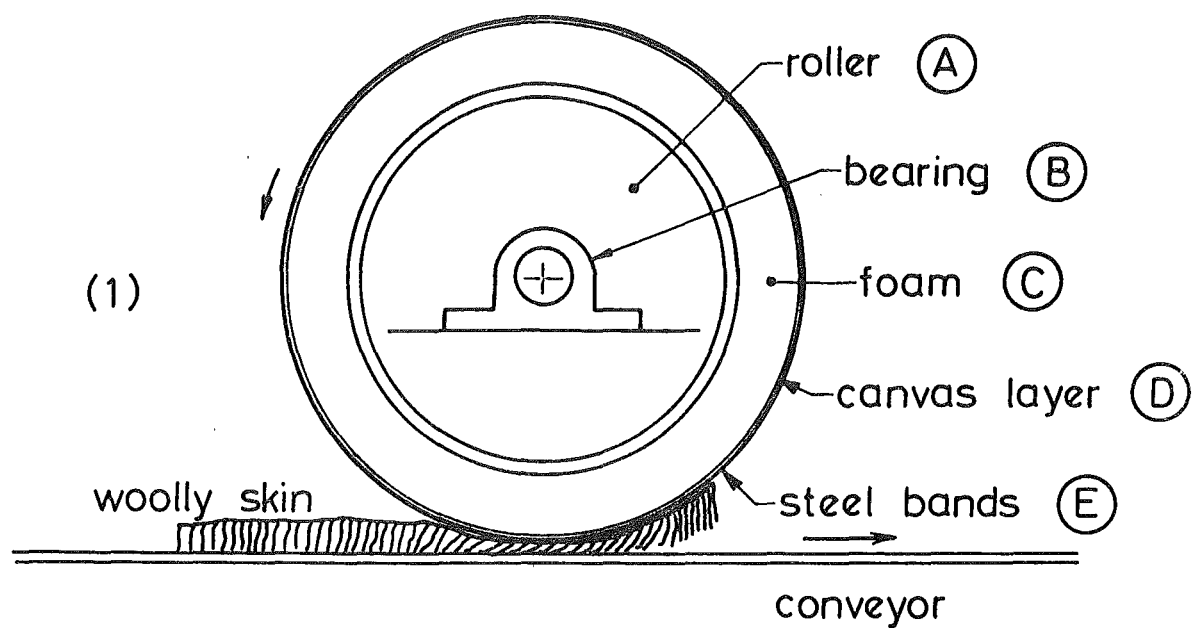
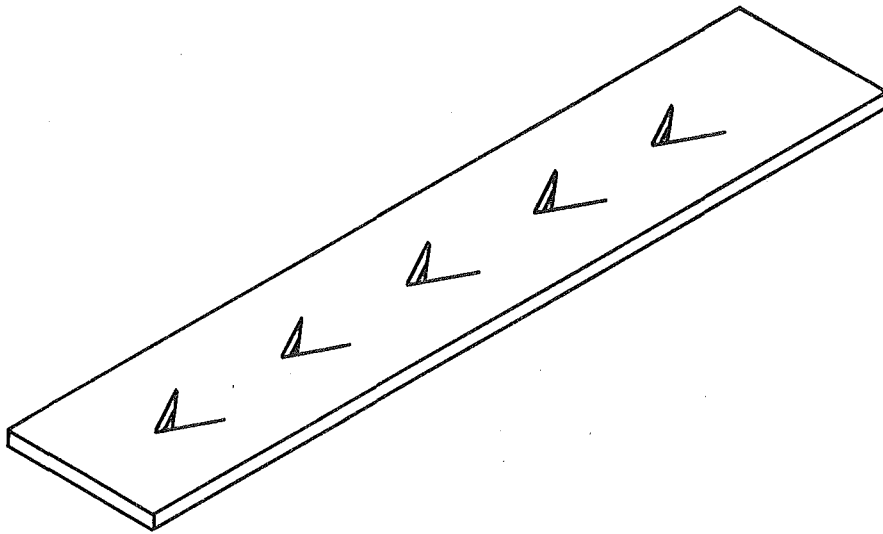
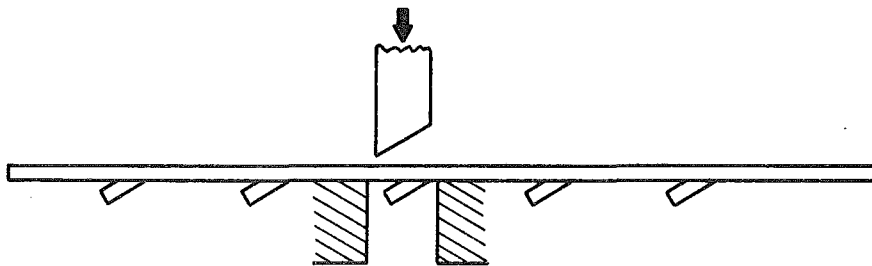


Fig 22 DIAGRAMMATIC REPRESENTATION OF THE WORKING OF THE EVANS ROLLER



Section of punched steel strip



Punching process



Punch cross section

Fig 23 PUNCHED STEEL STRIP

- a) It took woolly skins which had been carried on a conveyor wool side down, and presented them wool side up for cutting. As preliminary operations such as trimming are preferably done with the flesh side uppermost, this was an advantage for a holding system.
- b) It picked up the skins and held them in such a way that there was resistance to both sliding and lifting. As it was necessary to have the roller surface speed slightly greater than the feed-in belt speed, there was a stretching effect also.
- c) As the roller had a flexible backing it could accommodate variations in skin thickness.

The machine is represented in Figure 24. The original feed belt of the previous machine (A) had no foam cover in this machine. The Evans Roller (B) was mounted so as to run in contact with this belt. Directly above the roller and 180° away from the pick-up point, were placed the bandknife (C) and C.O.R. (D).

A three horsepower motor, driving through a reduction gearbox and variable pulley system, powered the roller.

Woolly skins were laid wool side down on the feed conveyor, and the Evans roller, moving slightly faster than the belt, gripped and picked up the skin. The skin was then carried up to the cam-operated roller and bandknife. As this was an experimental machine, no provision for pelt or fleece handling was made.

V.8.4 Machine Trials Before cutting trials began, a series of runs were made to determine the optimum speed differential between the Evans Roller and the feed-in conveyor for efficient

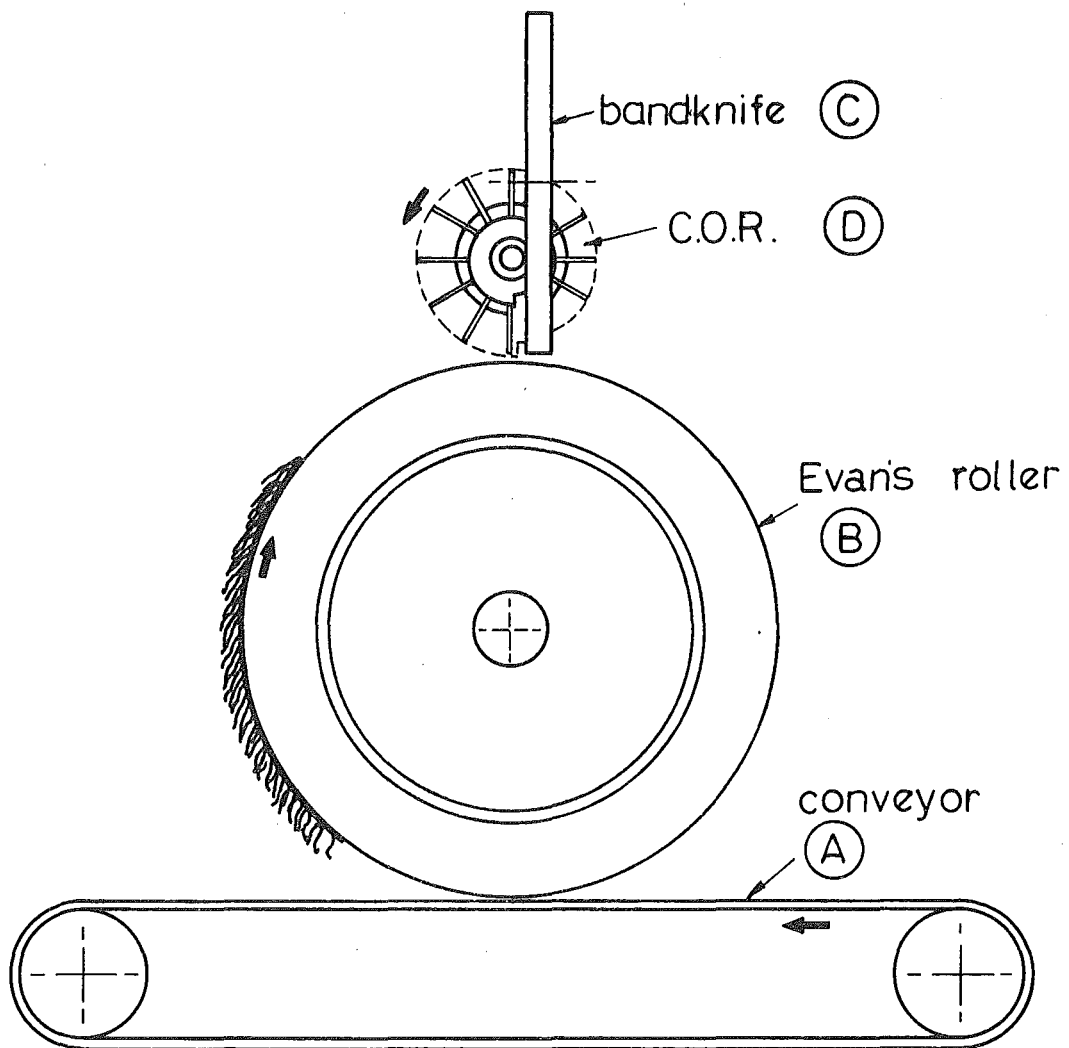


Fig 24 DIAGRAMATIC REPRESENTATION OF THE
MACHINE USING EVANS ROLLER

lifting of the skin.

If the surface speed of the roller was less than, or equal to the speed of the belt, the skin was not lifted. However, if the roller moved at too great a speed, the skin was overstretched and longitudinal wrinkles began to appear in the pelt.

Eventually it was found that a surface speed variation of 1.05: 1 was a suitable operating condition.

With the bandknife and C.O.R. positions adjusted in the same manner as described in IV.4, cutting tests were carried out using crossbred skins.

Again it was found that reliable cutting was not achieved. Despite the holding effect of the roller surface, buckling of the skin between the rows of spikes still occurred and total jamming of the system was common.

It was apparent that areas of the skin with fat adhering were not being held by the roller and, if they were near the leading edge, a folding problem was likely.

The effects of bandknife deflection were more apparent on this machine than earlier models.

V.8.5 Discussion and Decisions It was not completely clear which of two possible causes of unsatisfactory operation was dominant.

- a) The bandknife deflection may have been causing the damage. It was conceivable that an unstable effect like the increase/decrease of stubble length could occur more than once on a skin. This was hinted at by the occasional appearance of an undulating

length of stubble along the skin.

- b) The handling system still had an intermittent rather than continuous action.

It was decided to investigate the bandknife problems by building guides for the blade. In practice, the blade guide investigations were performed concurrently with other modifications, but for the purposes of systematization, they are described in the following chapter.

CHAPTER VI

BLADE GUIDES

VI.1 GENERAL DISCUSSION

Many commercial bandknife machines, which are required to make accurately positioned cuts, such as leather and plastic splitting machines, have the working length of the blade running in a slot in a rigid guide, with the sharpened edge protruding. In some machines this guide is a heavy steel or cast iron bar with a slot machined into it. In others, particularly where the clearance under or above the blade is critical, the blade moves between a pair of thin, but highly tensioned bands.

When the bandknife machine was constructed, there were three reasons advanced for not using a slotted blade guide :

- (a) Because of the higher than normal blade speed, fears were held that overheating or seizure of the blade in the guide might occur.
- (b) The slot was expected to be a potential cause of wool or wool particle jamming.
- (c) The presence of large amounts of metal below the blade was undesirable because the shorn skin was required to pass through the clearance between the blade and the backing material.

Because of the problems experienced with stubble length variation, which was apparently caused by the deflection of the blade, it was decided that a blade guide was necessary.

Moderate speed (64 frames per second) films of the machine

during cutting, and of the blade in particular, were replayed at slower speeds. Viewing of the blade was difficult, because the cut wool tended to cover the cutting area, but the films did suggest that the blade was twisting during cutting.

A diagrammatic representation of the blade deflection, and stubble length variation, is shown in Figures 25 and 26.

VI.2 DESIGN OF THE BLADE GUIDE

VI.2.1 General Considerations.

The requirements for the blade guide were divided into four groups :-

VI.2.2 Material Choice.

It was considered necessary to use a spheroidal graphite cast iron for the guide to prevent seizure at the operating speeds. Cast iron is self-lubricating to a small extent, and it was felt that the combination of the steel blade and cast iron guide, together with moisture and lanolin from the wool, would make any lubrication unnecessary. The use of lubricating oil was not desirable because of the contamination problems which might occur.

VI.2.3 Slot Clearances.

There were three reasons for having only small clearances above and below the blade :-

- (a) The blade could twist less if smaller clearances were used. Apart from the obvious advantage of control of the blade, less deflection in the slot lessened the possibilities of local overheating, caused by, for example, the rear edge of the blade rubbing on the slot surfaces.
- (b) Blade vibration was a possibility. During run-up

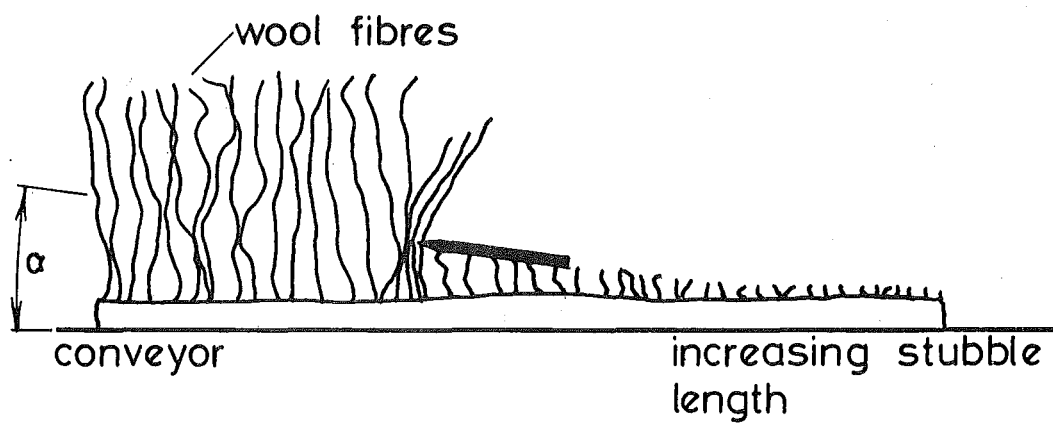


Fig 25 DEFLECTING BANDKNIFE α POSITIVE

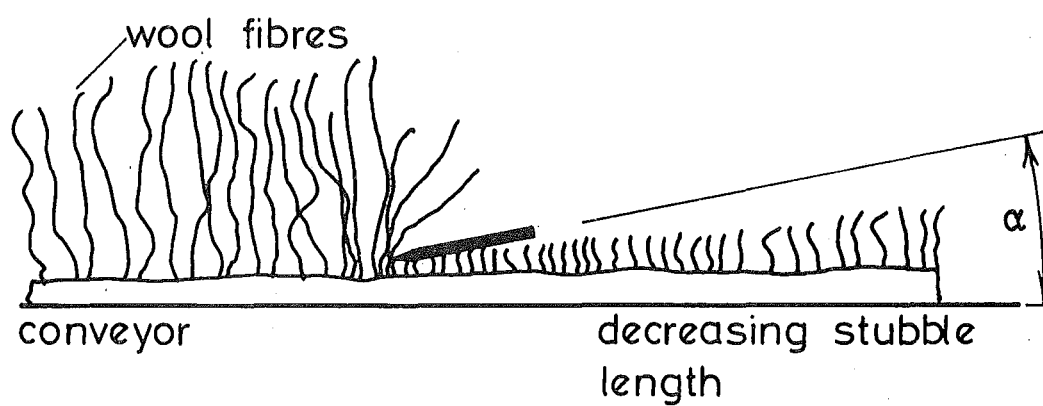


Fig 26 DEFLECTING BANDKNIFE α NEGATIVE

and run-down, the blade inevitably passed through a series of vibratory modes. It was expected that large clearances in the slot might intensify the effect because of blade chatter.

- (c) With a small clearance there was less chance of the ingress of wool or pelt particles.

However, there were reasons for having larger clearances :

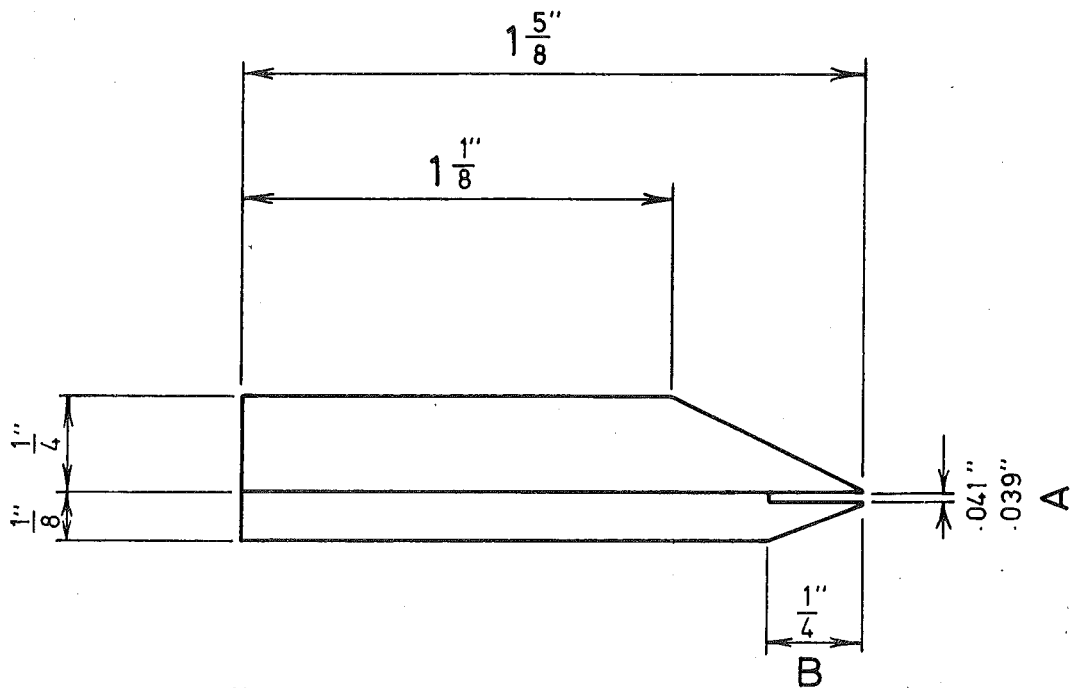
- (i) Frictional drag would be higher with small clearances, particularly if large amplitude vibrations occurred;
- (ii) If any foreign matter did enter the slot, seizure would be more likely with small clearances than with large.

It was decided to try a clearance of .004" total between blade and guide. As the blade was of half inch depth, a slot of depth one quarter inch was machined.

VI.2.4 Stiffness of the Guide.

It was important to have as little solid material under the blade as possible. Most of the stiffness of the guide was required to be contributed by the upper guide. A ramp face for the wool and pelt to slide over was required on both upper and lower guides.

The profile used is shown in Figure 27. The guide was made in two halves, for ease of machining, and possibly, later modification. The thin lower guide was screwed to the large upper guide using countersunk screws.



Note: Bandknife dimensions

$$A_1 \times B_1 = .036" \times \frac{1}{2}"$$

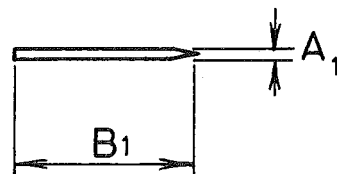


Fig 27 PROFILE OF BANDKNIFE GUIDE

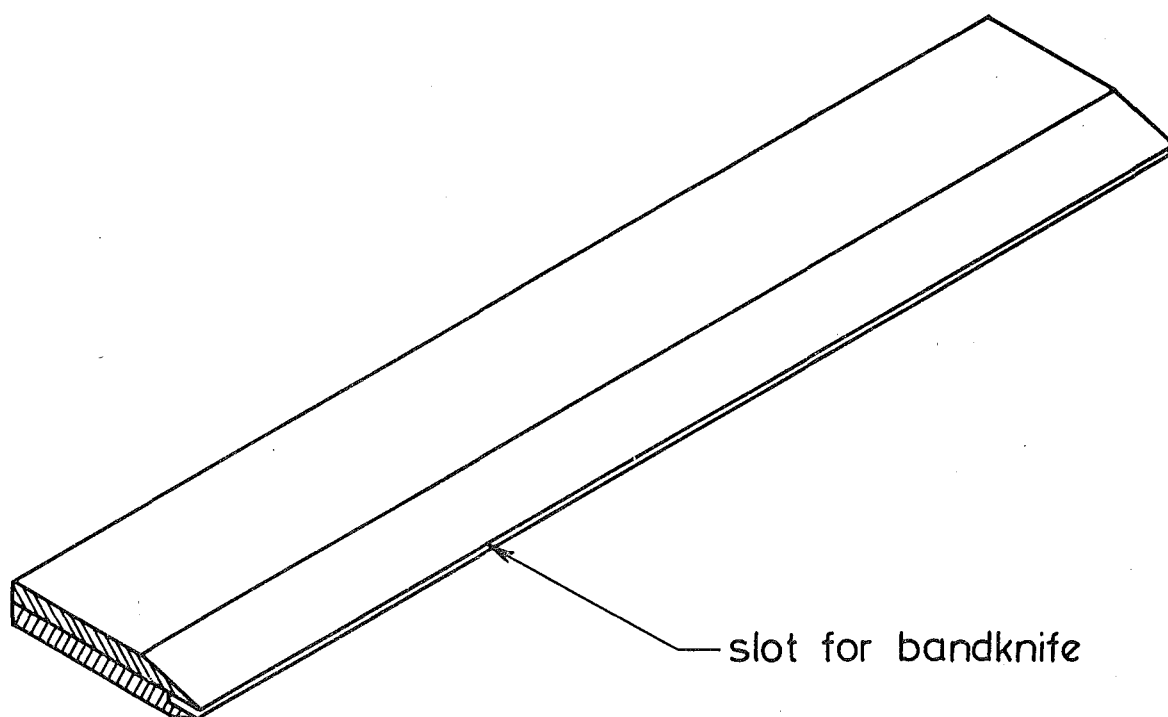


Fig 28 BANDKNIFE GUIDE

VI.2.5 Control of Blade Position.

As the blade depth was reduced by sharpening, the length of protruding blade was decreased. Although this could be compensated for by moving the blade guide rearward relative to the edge, and relying on the crown effect of the bandknife wheels to position the edge, it was expected that movement might occur during cutting.

Consequently, thrust bearings were used to prevent rearward movement of the blade. These were mounted at each end of the blade guide, with the blade running just clear of the tungsten faced, ball thrust bearings. (See Figure 29).

VI.3 TESTS OF THE BLADE GUIDE

The blade guide was tested by running for fifteen minutes under no load. After this time the blade and guide temperatures had risen only some 2°C , and there was no sign of seizure.

Woolly skin trials were carried out, and as far as could be judged using the existing handling systems described in the last chapter, no adverse effects were noticed. The lower guide did not prevent the pelt from passing under the blade, and the wool passed easily over the upper guide.

However, the test runs showed that the stubble length still increased or decreased, as it did with an unguided blade. Although the blade could no longer deflect far enough to produce this effect, the backing material could. During tests with the blade edge facing up relative to the skin, the

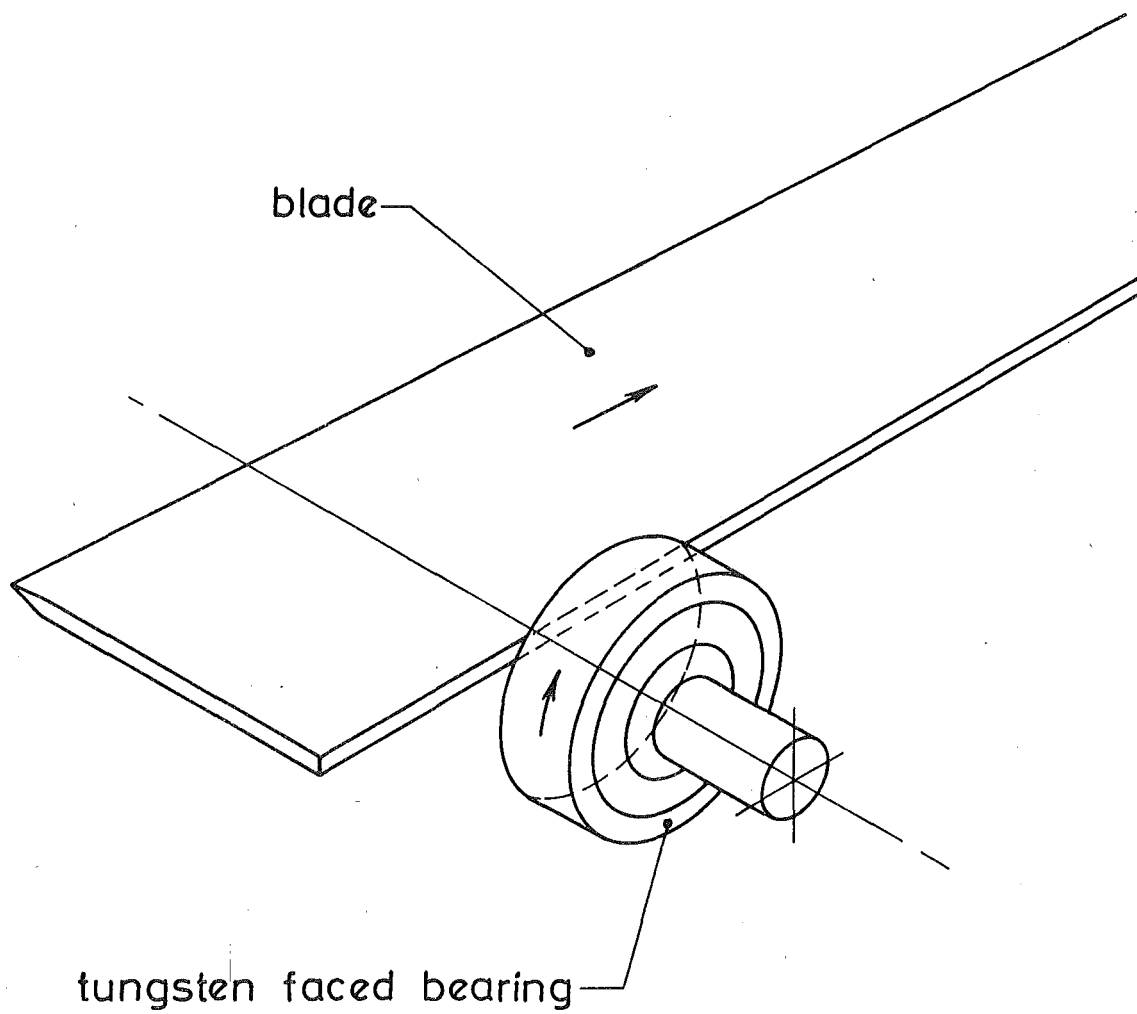


Fig 29 BLADE THRUST BEARING ARRANGEMENT

stubble length increased as the backing material compressed. When the blade pointed downwards, it appeared that the skin began to lift from the backing. The expected mechanisms are sketched in Figures 30 and 31.

VI.4 DISCUSSION OF THE TESTS

The guide was shown to be successful, in that it produced no noticeable adverse effects, and also guided the blade. However, a basic weakness of resilient backing systems had been revealed. It was now becoming clear that a more positive means of holding the skin was needed if the open slot blade guide was to be used. However, there was the possibility of shielding the skin from the edge, and using the tendency for a downward inclined blade to cut into the skin to form a feeding system.

Consequently, it was decided to design a modified blade guide, incorporating a shielding system.

VI.5 THE MODIFIED BLADE GUIDE

A new lower guide was made, and this is shown in Figure 32. This had small combs or teeth projecting forward a small distance from the blade edge. This distance could be altered by sliding the lower guide relative to the upper guide.

This clearly was not dissimilar to the combs tried earlier, except that the physical size of the teeth, and the distance the teeth were required to penetrate, were considerably smaller.

The expected distance from the teeth ends to the blade edge was $1/8$ " to $1/4$ ", but provision was made to adjust from $3/8$ " to $1/4$ " behind the edge.

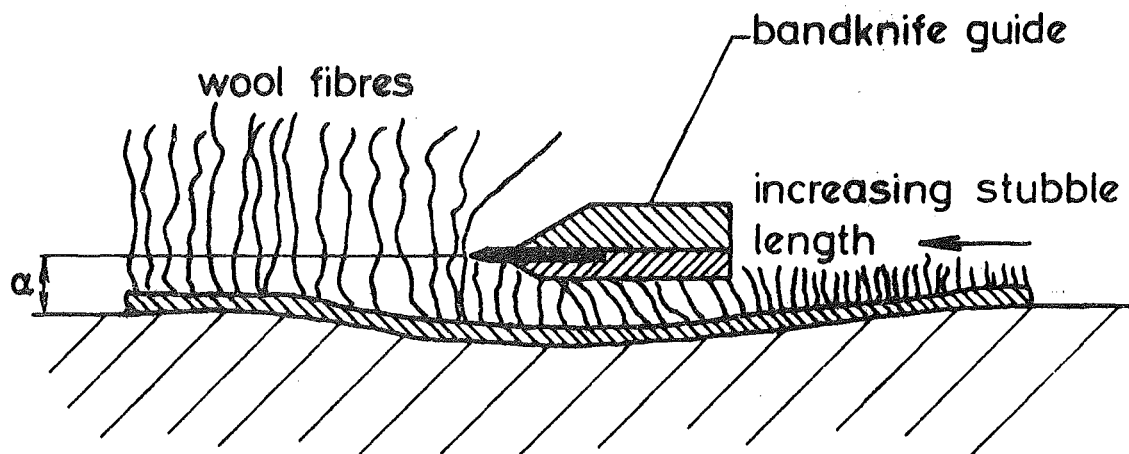


Fig 30 DEFLECTING BACKING α ZERO OR POSITIVE

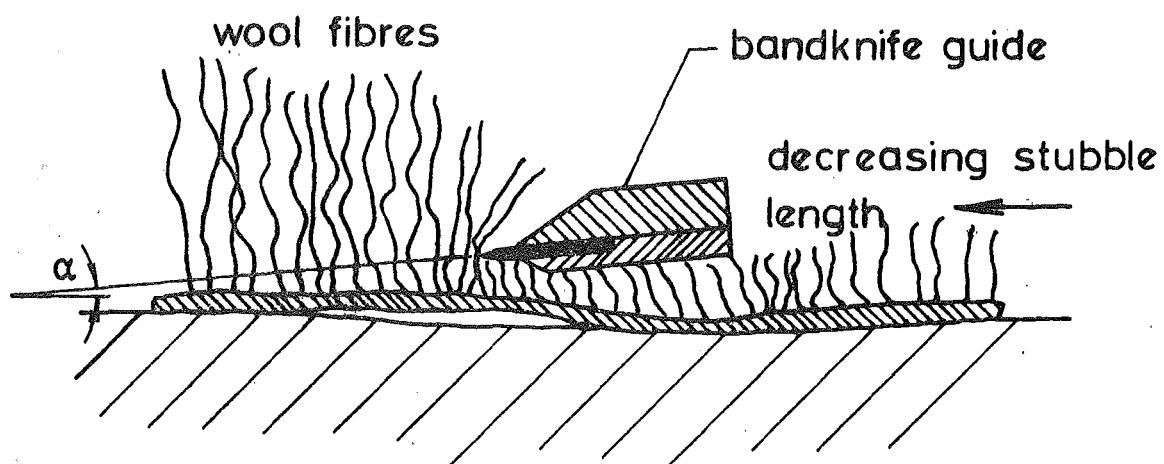


Fig 31 DEFLECTING BACKING α NEGATIVE

The method of producing the teeth by a series of milled slots is represented in Figure 32. The sharp edges left by the machining were faired off with a hand file. Because of the shape of the teeth, it was preferred that steel be used rather than cast iron. The advantages of the cast iron guide, namely its good frictional properties, were lost by doing this, but the upper guide was still of cast iron.

VI.6 TESTS OF THE MODIFIED BLADE GUIDE

No load tests showed that, despite the steel lower guide, continuous operation did not result in seizure.

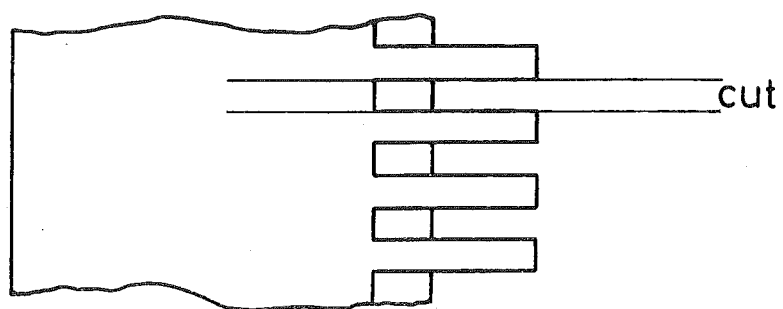
When woolly skins were fed into the machine, jamming always occurred, unless the teeth did not project past the blade edge.

When clean, dry and unmatted skins were used, the effect persisted, thus eliminating a matting effect.

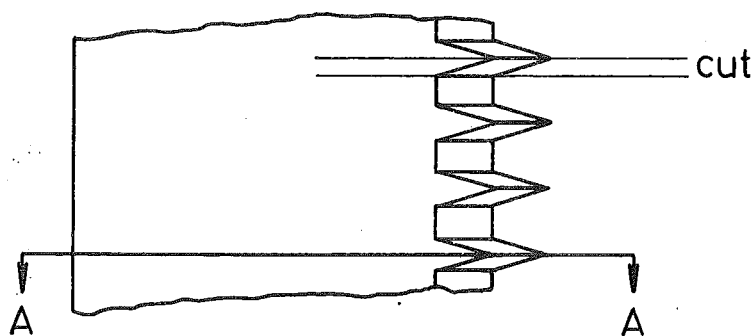
It was thought that, with a greater resisting force than that supplied by the Evans roller, the problem might be reduced, but the chances of such a system producing a reliable performance were considered low, because of the earlier experiences with comb systems.

VI.7 EFFECTS OF THE TESTS ON THE PROJECT

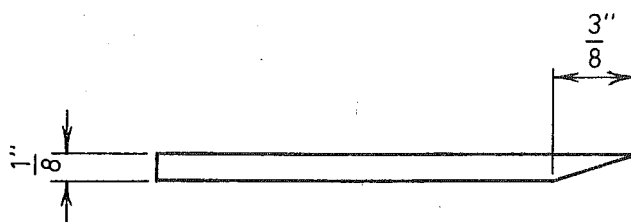
The attempt to overcome the disadvantage of resilient backings, namely that of stubble length variation, by introducing a shielding system, and relying on operation on one side of the neutral position, had not been successful.



Stage One



Stage Two



Section A-A

Fig 32 COMB TEETH PROFILES

The result was that resilient backings had been demonstrated to be unsuitable for bandknife cutting, at least within the types of systems experimented with in this project.

Consequently, spike penetration and wool side location were similarly shown to be impractical. Attention then moved to flesh side location, and this is discussed in the next chapters.

The performance of the machines using spike penetration was not considered reliable enough to carry out blade profile investigations or wear tests.

Further developments of blade guiding for long term operation is discussed in Chapter IX.

CHAPTER VII

FLESH SIDE LOCATING SYSTEMS

VII.1 ALLOWABLE STUBBLE LENGTH CRITERIA

At the time when the project began a cost/benefit analysis of Cutting of Wool from Sheepskins was carried out by Stewart, R.G.¹ of the Wool Research Organisation of New Zealand. The economics of wool shearing as opposed to depilation had been based on a residual wool length of five millimetres. Later investigations showed that, as a result of changes in wool and pelt values, a greater length could be tolerated. The effect of an increased residual stubble allowance on the proposed holding systems was very important. Skins do not have a uniform skin thickness. In particular, the area around the neck is often thicker than the flank region and the variation is of similar magnitude to the allowed stubble length (often 3-4 mm).

Consequently, following both the recognition of the allowable stubble increase and difficulties encountered with the wool side location systems, flesh side locating processes were considered.

The foregoing discussion refers to locating systems using single plane cutting devices such as the continuous bandknife. Alternatives, such as a row of hand shearing pieces arranged so as to follow the skin contours, were seen as possibilities but not as practical schemes for continuous operation without a great deal of development. The relative simplicity of a bandknife, as well as its suitability for continuous operation and its proven value in shearling cutting, indicated that a bandknife system should be investigated.

VII.2 POSSIBLE FLESH SIDE LOCATING SYSTEMS

Mechanical systems, such as the Evans Roller (refer Chap.V) were considered to be impractical because:

- a) The holding force had proved insufficient on the Evans system, and
- b) No system which used a continuous gripping system had been devised.

Suction systems, such as those used in the Selbeck and W.P.M. machines, offered the advantages of:

- a) Uniform force over the skin area, and
- b) Relative simplicity of construction.

It was decided that, despite the less than satisfactory performance of commercial bandknife machines using suction systems to hold the skin, this type of locating system would be developed.

VII.3 CONSIDERATIONS OF SUCTION SYSTEMS

The requirements for a successful holding system could be divided into four groups, already broadly outlined in the overall requirements for shearing machines (ref.Introduction).

VII.3.1 Sufficient Holding Force The skin was to be held in such a way that during the cutting operation no sliding, folding or lifting of the skin, relative to the backing material could occur. This basic consideration was satisfied by the commercial machines, at least when they were run under their designed conditions of speed, length of cut and operator skill.

VII.3.2 Adequate Throughput In order to be economically justifiable, the machine and, consequently, the feed, holding

and cutting systems had to be able to handle 600 skins per hour according to Stewart's analysis.

As the commercial machines failed to meet this demand it was apparent that much of the development work would be in this area of speed increase.

However, it should be noted that a machine handling, say, three hundred skins per hour, but designed with a double table width, allowing two skins to be cut at once, could also satisfy those conditions.

VII.3.3. Operator Sensitivity For the rapid production line type operations of freezing works in New Zealand, a minimum of machine attendants was desirable. Again, all parts of the machine were subject to this requirement.

VII.3.4 Continuous Operation It was essential that the machine systems were capable of continuous operation, without enforced shutdowns for cleaning, adjustment, etc. However, twenty-four hour operation was not expected as most works close down from late afternoon to early morning.

VII.4 DESIGN CONSIDERATIONS OF SUCTION SYSTEMS

The basic requirement of a suction system for holding a skin was that air be taken from beneath a porous surface, which had to be of sufficient strength to hold the skin in one plane and be capable of moving the skin to the bandknife.

Previously, machines had been constructed with a porous conveyor belt passing over a fixed plenum chamber and under a bandknife. As the belt moved the skin under the knife, the airflow held the skin against the moving belt thus increasing the force needed to slide, fold or lift the skin.

Two possible porous materials were considered usable. These were the wire mesh conveyor belt and the punched metal plate. The wire mesh belt had been used in other machines and the use of punched metal plate in wool drying drums was common. It was decided to use a punched metal plate surface, rolled into a cylinder, (A) in Figure 33, and arranged to pick up the skin from a feed-in conveyor (B) and carry the skin to a band-knife (C). This was of similar principle to the machine using the Evans Roller.

The reasons for this choice were:

- a) Uniform Surface: A punched metal cylinder has a uniform and rigid surface, unlike a mesh belt which has an irregular surface and needs some support to maintain any of its path in a constant position. Investigations of the local market and abroad, revealed no porous conveyor material with a smooth surface.
- b) Trimming: As it was expected that trimming of the legs would still be a necessary step in the process, consideration was given to the requirement that the woolly skin be flesh side up for trimming and spreading (The reason for this is that the trimming knives rapidly become blunt if they cut through the wool rather than just the skin). It was difficult to arrange a suction and conveyor system to work in this manner because investigations into the spreading of woolly skins had revealed that transfer of a skin from one belt to another in a stretched out state was impractical. However, a suction drum, lifting the skin from the feed-in and trimming belt, could easily fulfil this requirement.

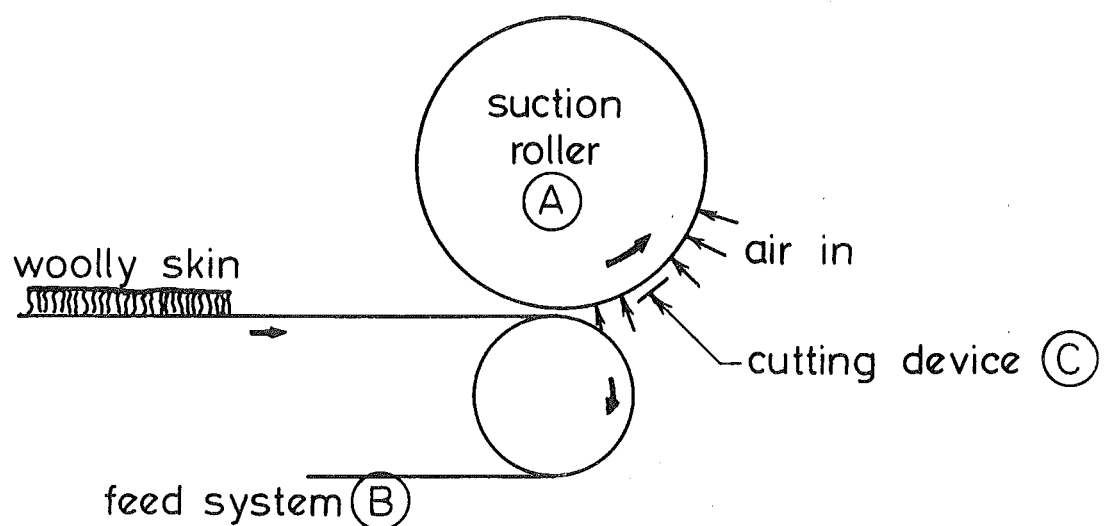


Fig 33 PROPOSED SUCTION SYSTEM

- c) It was expected that it would be advantageous to cut the wool while the skin was being held on a curved surface, thus opening the fibres.

While either system could be designed to achieve this, the conveyor system demanded a more complex design process to achieve the same result because, normally, rollers support any curved part of the belt and these would then be in the space where a plenum chamber should be, thus leading to the adoption of a belt rubbing on a curved chamber.

VII.5 INITIAL DESIGN OF SUCTION ROLLER

A number of design criteria were apparent:

- a) Internal baffling of the roller was necessary to restrict airflow to only the required area, thus reducing the power requirements.
- b) An air extraction system with low leakage rates from the stationary and moving parts was required.

It was also apparent that an investigation into the properties of punched metal plates under a pressure drop, and the forces thereby exerted on skins held on these surfaces, was needed to determine the practicability of the system.

VII.6 THE POROUS SURFACE EXPERIMENTS

VII.6.1 Objects of the Experiments The previously listed requirements of resistance to sliding, folding and lifting of a skin on the surface of a suction roller, were functions of the roller surface and the flow through it. The aim of the tests performed on porous surfaces was to determine the most suitable material from which to construct the roller surface.

VII.6.2 Experimental Apparatus and Method A test rig was constructed. This consisted of an open topped cubical plenum chamber ((A) in Figure 34) from which air was taken via a duct (B) by means of a centrifugal fan (C). The open top of the box could be covered with punched metal plate samples (D) and skin samples (E) were placed on top of these. The skin samples were small rectangles cut from woolly skins. A clamp (F) on one edge was attached to a spring balance to measure the force required to move the sample.

A manometer (G) recorded the pressure inside the chamber and a pitot tube (H) was used for flow measurement in the duct.

Initially, a Richardson type O.B. centrifugal fan, driven by a one horsepower motor via a varispeed unit, was used. Later tests were carried out with a Richardson 3½ VB fan and 10 horsepower motor.

With the O.B. fan, the flow was varied by changing the fan speed. A gate in the duct was used with the 3½ VB fan.

With the smaller fan there was provision for relative power measurement also.

During test runs the skin samples were washed before and after sliding on any surface so that the flesh did not become contaminated and possibly change its characteristics. With the fan running and the sample in place, the pressure in the chamber was noted and the limiting force required to slide the sample measured.

Similarly, coefficient of friction tests, with weights being placed on the skin when there was no airflow from the chamber, were carried out.

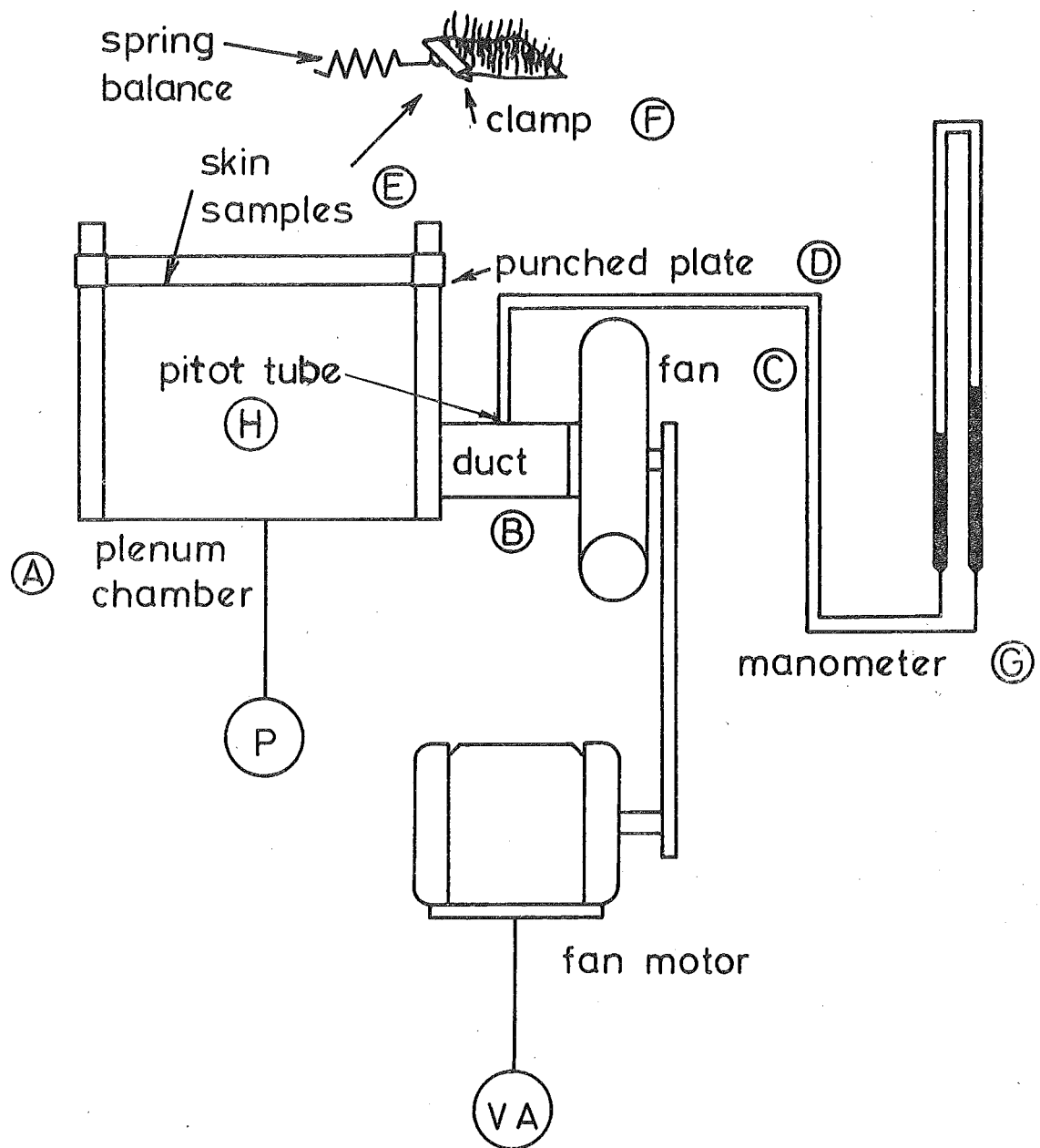


Fig 34 SUCTION EXPERIMENT APPARATUS

VII.6.3 Types of Porous Material Two classes of porous material were investigated:

- a) Punched steel plate: of 18 gauge thickness
- b) Woven wire mesh: both brass and stainless steel.

It was expected that, although the roller was to be made of punched steel plate, there could be a need for a covering of wire mesh to provide a more even distribution or to decrease the open area.

Punched steel plates of the following sizes were used:

Plate No.	Hole Size (Number Drill)	Holes/sq.inch	Open Area Ratio
1	24	23	.42
2	30	32	.40
3	52	88	.30
4	56	128	.19

Wire mesh of the following specifications was used

(B indicates a brass wire, S stainless steel)

Mesh No.	Wires per Lin. Inch	Wire Diam. (ins.)	Open Area Ratio
S20	20	.015	.5
S50	50	.009	.32
S80	80	.005	.36
B30	30	.010	.5
B60	60	.007	.32
B80	80	.005	.36

VII.6.4 Coefficient of Friction Tests In these experiments only the action between the skin side of the woolly skin and the plate or gauze, was important. All tests were done with

the sample spread skin side down.

Because of the flexibility of the skin it was difficult to tell if all or just part of the sample was moving. Consequently, the maximum steady force which could be applied without the leading edge moving was taken as the limiting condition. (In a machine, the skin could lift or slide in one area but not in another, hence this criterion seemed reasonable). It was necessary to average a number of readings to achieve a consistent result.

In order to ensure a flat surface, when wire mesh was combined with the plates, the clamp shown in Figure 35 was used. The wire mesh, laid on the plate, was held flat by pushing on the wooden block (A). The clamp (B) which fitted round the block and sandwiched the protruding wire mesh, was lowered into place and fastened down by tightening the thumb-screws (C) onto the extensions of the chamber legs (D). The wooden block was then removed leaving the wire mesh flat and gripped at the edges.

It was expected that the pressure drop on the suction roller would be under one foot of water (nearly one half pound per square inch) so weighting was required to this pressure only.

The results (see graph, Figure 36) show that:

- a) In this range of pressures, the coefficient of friction remained substantially constant for clean, wet skin on the various materials.
- b) There was very little difference in frictional properties between the punched metal plates of various sizes and the wire mesh samples. The

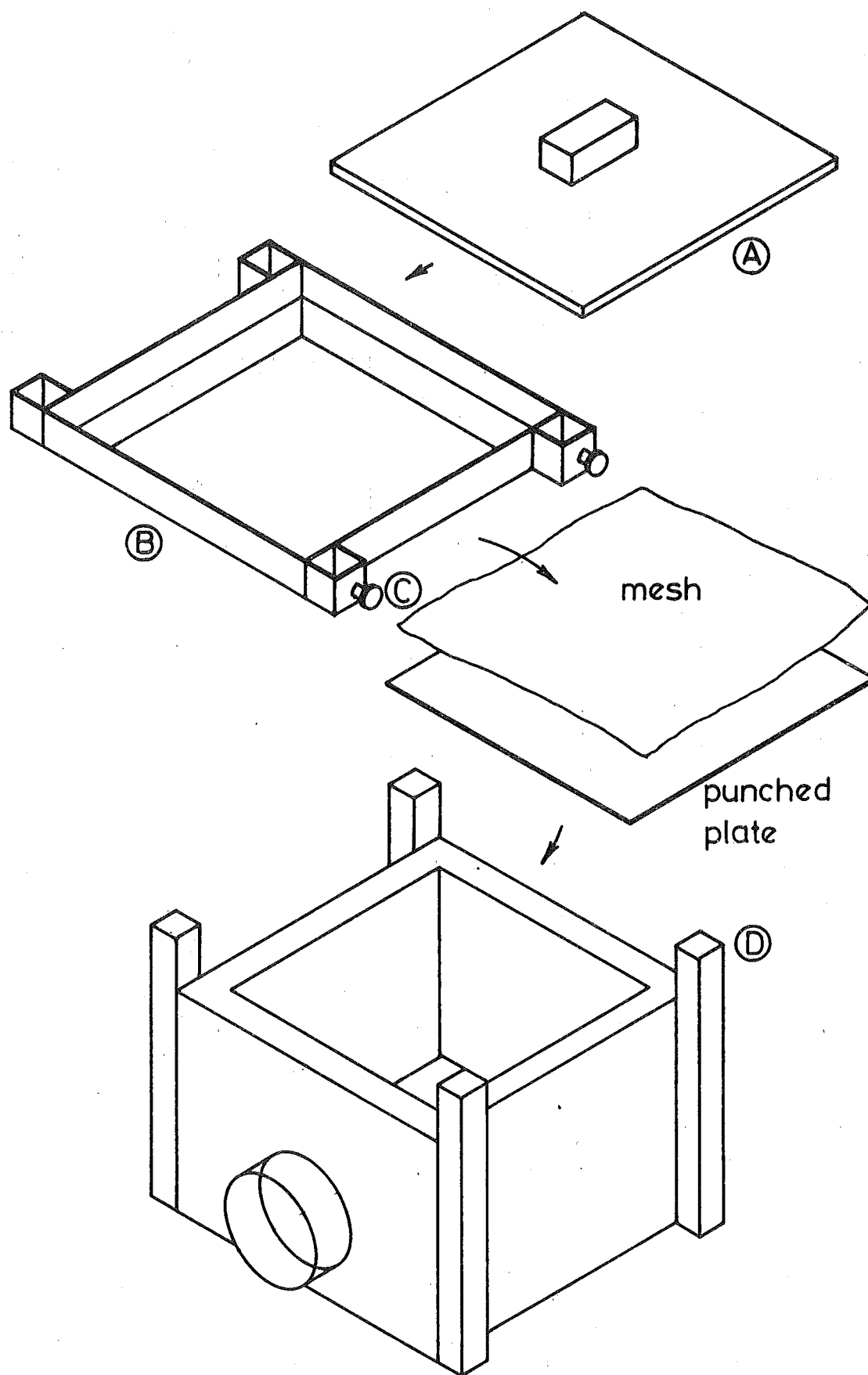


Fig 35 PUNCHED PLATE & WOVEN MESH CLAMP

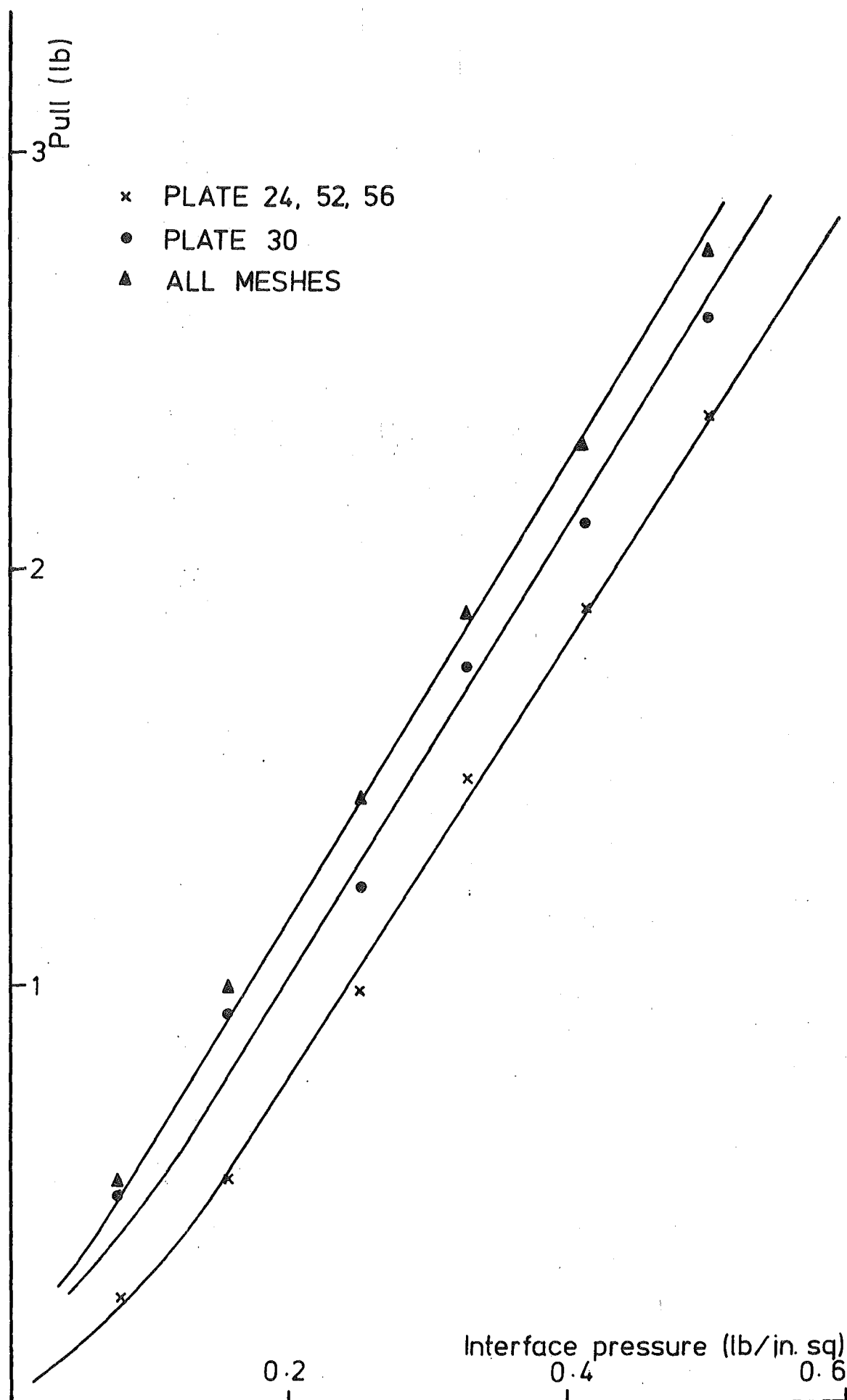


Fig 36 COEFFICIENT OF FRICTION TESTS

value of μ , the coefficient of friction for green sheepskin on punched metal plates, came to approximately .4, and the figure for gauzes was indistinguishable within the experimental error.

VII.6.5 Sliding Tests with Airflow During test runs with the Richardson O.B. fan, pressures reached in the plenum chamber were less than those expected to be necessary in the suction roller. Although the larger 3½ VB fan became available, it had no provision for power measurement and the equipment to measure this was not readily available.

Consequently, the low pressure results were extrapolated and the higher pressure results used to check some areas to ensure the validity of that method.

As vibration transmitted to the plenum chamber from the fan influenced the sliding force, particularly at low pressures, weights were added to the skin samples to reduce this effect. As the coefficient of friction was known to be linear at low interface pressures, the additional resistance to sliding, due to the pressure drop, was easily measured.

The results are tabulated and the graphs are included in Appendix II.

In general, it was noted that, for a given pressure drop, the force to slide the sample across a surface was lower when a woven wire mesh was used. The exception was for No.52 plate where a decrease in force was recorded when the plate was uncovered. Clearly, the condition of the surface was important and the meshes and plates were cleaned in carbon tetrachloride between tests.

A decrease in the amount of power required to produce a given pressure was noted when wire meshes covered the plates. In some cases there was a ratio of up to five between uncovered plate and covered plate.

However, mesh covers were not considered practical for two reasons:

- a) Although the maximum recorded value of the ratio sliding force/power was achieved with a mesh covered plate (see Appendix II), this ratio exceeded the maximum ratio achieved by an uncovered plate by only 45 percent, and
- b) There were technical problems associated with the fastening and cleaning of mesh covers. This was demonstrated during the experiments, when difficulty was experienced in maintaining the mesh as a level surface.

The power required to produce the resistance to sliding was not considered as important as the achieving of a regular suction roller surface.

Consequently, the graph of sliding force vs. open area for constant pressures was used to select a suitable plate (Figure 37) and a graph of headloss vs. open area, taken from a fluids text⁴ was used to calculate the flow through the system (refer Appendix III).

VII.6.5 Discussion of the Test Results From the results a number of design criteria were evident:

- a) The optimum open area plate was likely to be in the range $r = .35 \rightarrow .45$.

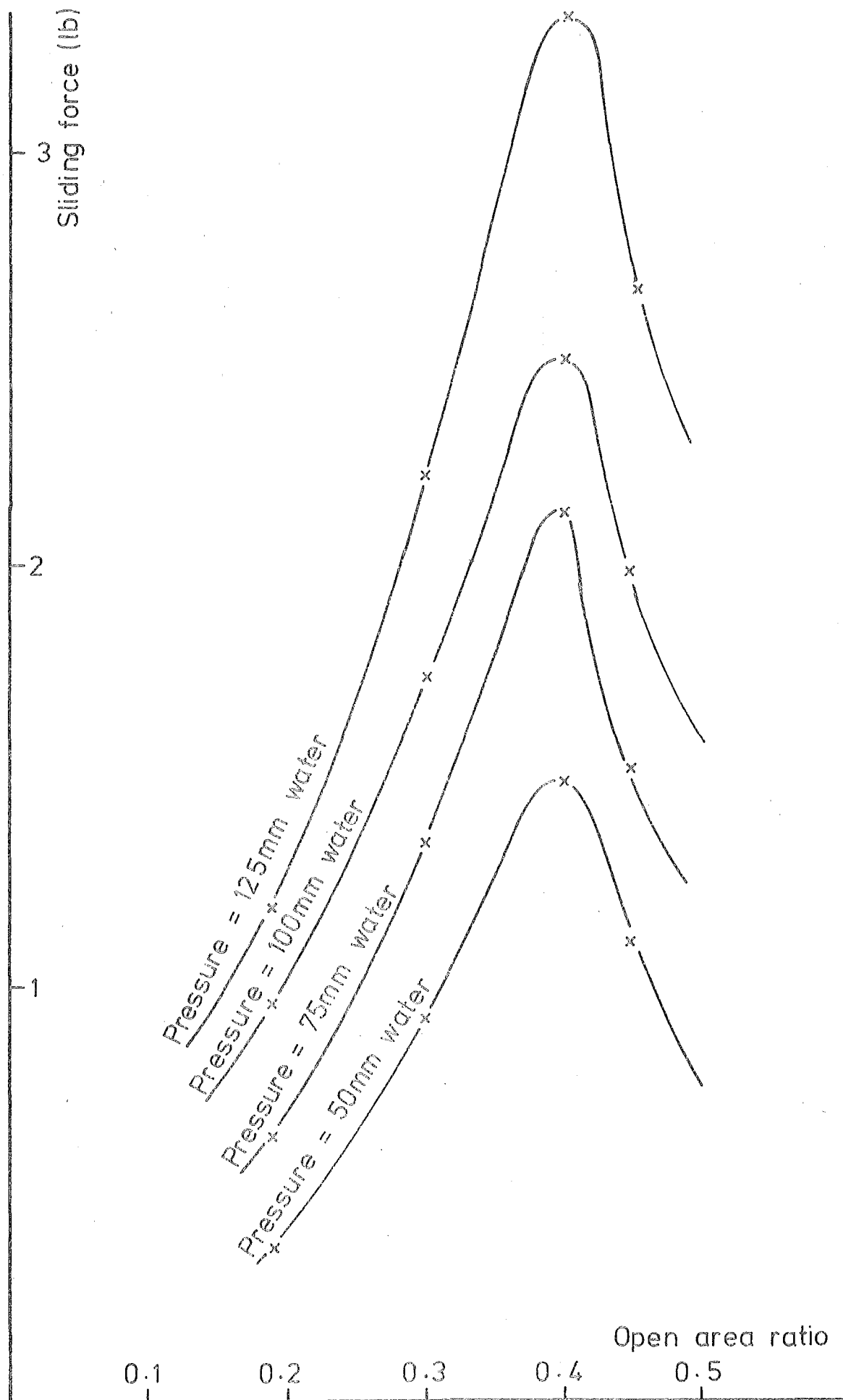


Fig 37 FORCE vs OPEN AREA, PUNCHED PLATES

- b) Calculations showed that the pressure required to produce a suitable force on the skin, on a porous surface, was obtainable with centrifugal fans.

As a consequence, it was decided to proceed with the design of the suction roller.

VII.7 FURTHER DESIGN OF SUCTION ROLLER

VII.7.1 Initial Design There were restrictions on the sizing of the roller imposed by practical requirements. Punched metal plates were obtainable in plates of six by three feet only. The maximum roller diameter for a one sheet roller then became $\frac{36}{\pi} = 11\frac{1}{2}$ inches. Other restrictions, imposed by available sprocket sizes, limited the exit pipe to six inches internal diameter steam pipe.

The results from the punched metal plate airflow tests were used to calculate the size of fan needed. It was estimated that a pressure drop of four inches of water was needed to hold and lift the skin. As the values of the cutting forces and stubble drag were not known, this figure was an approximation.

The calculations of the flow through the system may be found in Appendix III. A Richardson $3\frac{1}{2}$ V.B. centrifugal fan was found to be capable of producing a pressure drop of four inches in the roller, provided a length of only eight inches was left unbaffled.

VII.7.2 Details of Roller Design The suction roller is shown in Figure 38. The central pipes (A) had flanges (B) joined by staybolts (C) which ran down the interior of the roller. On each pipe was an end plate (D) which could revolve, using the pipe as a bearing. The rolled cylinder of punched

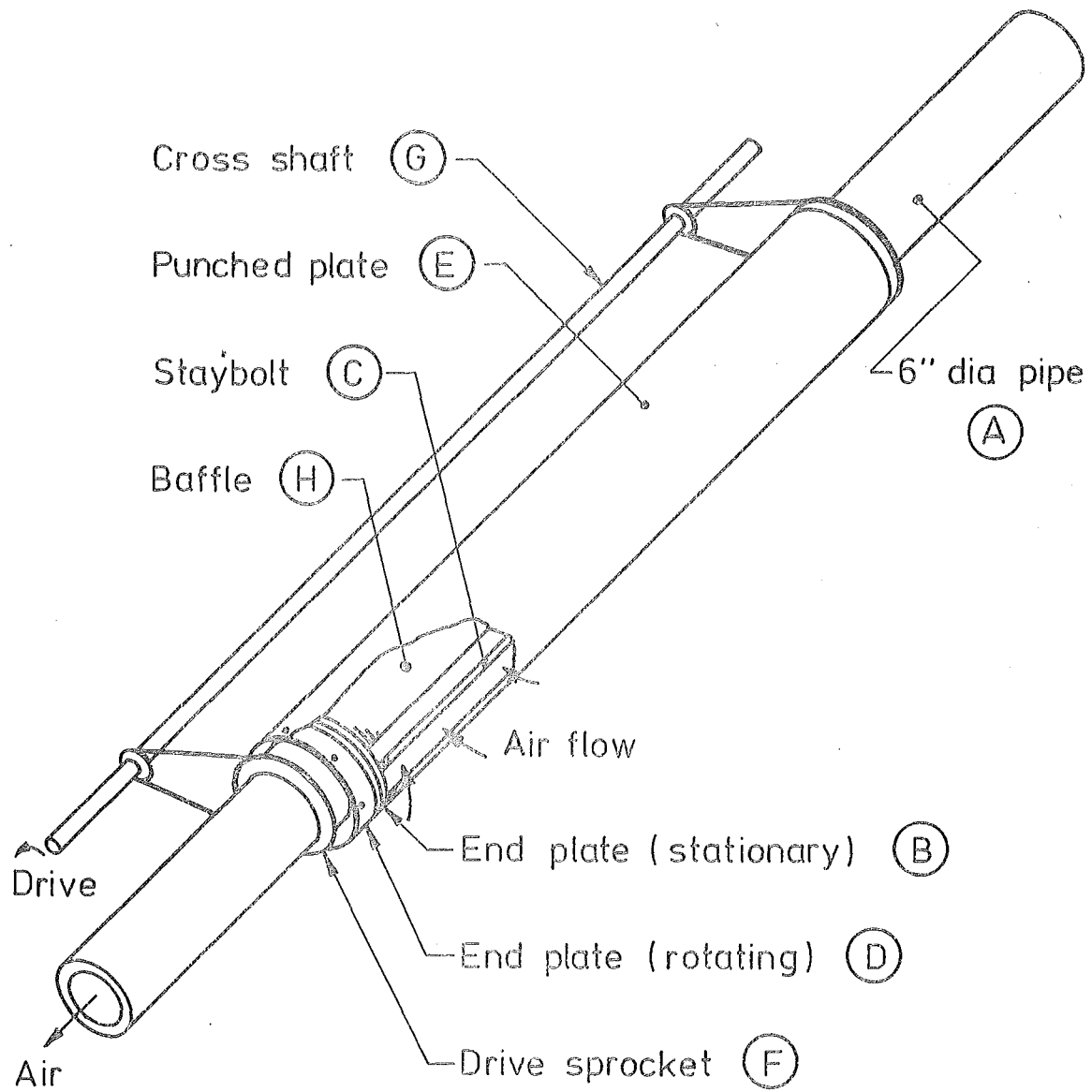


Fig 38 SUCTION ROLLER

steel plate (E) was attached at each end to these endplates. A plate sprocket (F) was bolted to each endplate, and these were driven by chains from a cross-shaft (G). A one horsepower variable speed motor and fifteen to one reduction gearbox drove the system.

Baffle plates (H) were attached to the flanges, inside the roller. These covered the interior surface of the punched cylinder, except for an eight inch deep band of open area.

The central pipes were the main structural support members. The pipes were held by clamps((A) in Figure 39) at each end of the roller. By loosening the clamps the stationary parts of the system, i.e. the pipes, staybolts and baffles, could be rotated. This allowed adjustment of the position of the suction area relative to any fixed object. Alteration of the area dimensions necessitated dismantling of the roller.

The clamps holding the roller were welded to rotatable platforms((B) in Figure 39) to provide a vertical adjustment of roller position. One of these platforms also carried the drive motor and reduction gearbox (C). The platforms were supported by the brackets (D), themselves part of a slide system on the top of the main frame units (E). Horizontal adjustment of the roller position was thus possible.

A ducting system took the extracted air from the roller to the fan, from one end of the roller. The other exit was blanked off.

It was possible that skins might tend to stick to the roller and, consequently, the provision of a blowing system, working on an area of the roller adjacent to the suction band, was planned but not built at this stage.

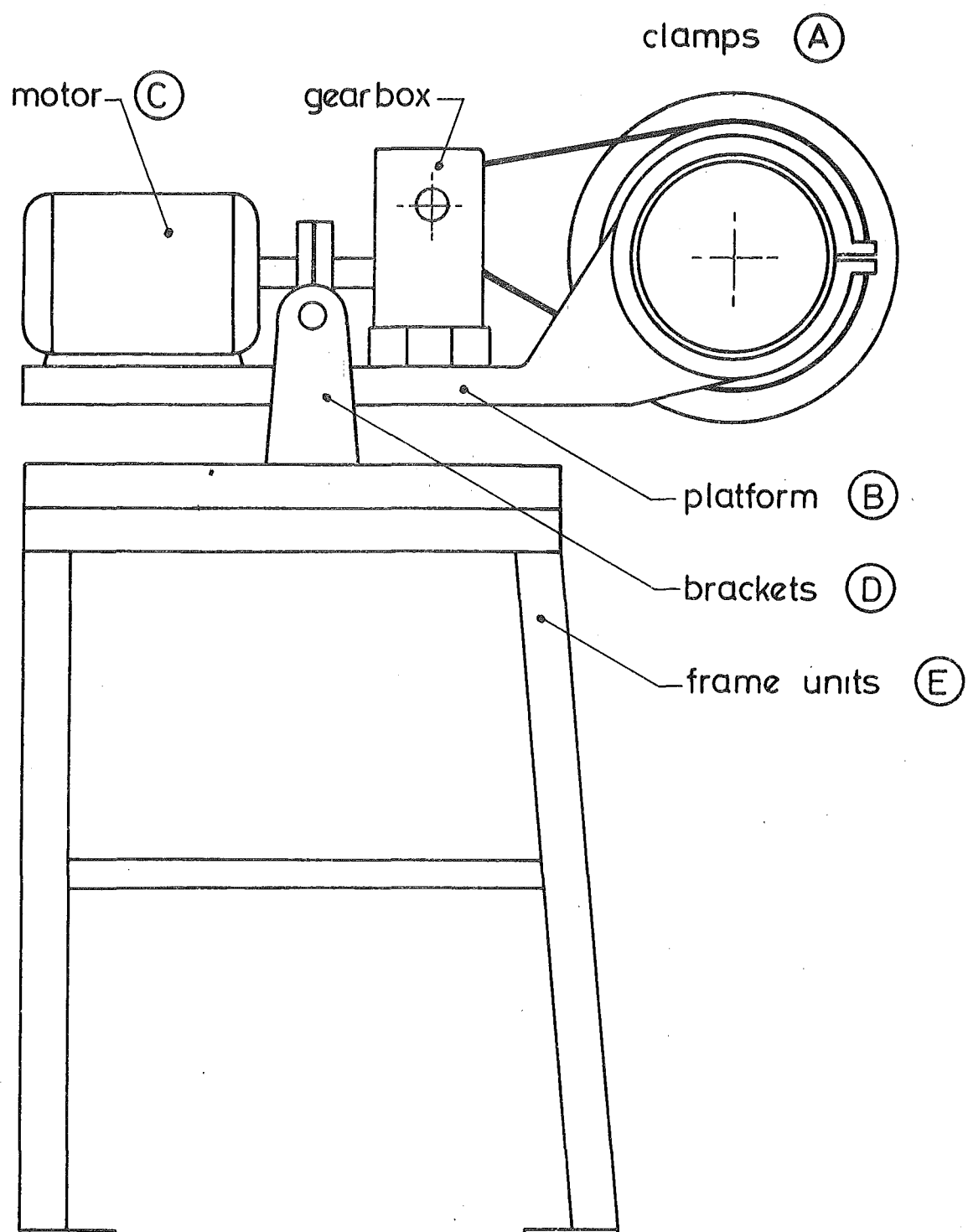


Fig 39 SUCTION ROLLER SUPPORT SYSTEM

VII.8 PERFORMANCE OF THE SUCTION ROLLER

Pressure measurements along the length of the roller open area showed a gradient of .02 inches w.g./inch from the highest pressure of three inches w.g. to the lowest of two inches. This was expected but, as the skin would be covering the greater part of the open area during cutting, it was not considered necessary to modify the baffling.

The average pressure in the roller was 25 percent lower than calculated. It was considered that this was caused by low assumptions of the entry coefficients to the pipe system. However, the working ability of the roller was the crucial factor. Tests showed that, although the roller would hold a skin in place, once it was pressed over the suction area, heavy skins could not be lifted from the feed-in belt.

There was little alternative but to use a larger fan to produce a greater flow and greater pressure drop. Calculations were based on a requirement of a 10" w.g. pressure differential in this case. From the calculations (Appendix III) it was clear a larger fan, of the Series 4 range of Richardson fans, was required. When this fan was used an average pressure of 9.5" w.g. was recorded, and holding and skin pick-up were satisfactory. However, until the roller could be included in a cutting machine, its effectiveness could not be accurately judged.

It was expected that the use of such a large fan (50 horsepower input) could be avoided by suitable ducting design. However, at this stage of the project, it was decided that the approach to the problem was one of making the system work rather than investigating air flow phenomena.

CHAPTER VIII

THE EXPERIMENTAL BANDKNIFE MACHINE

VIII.1 REQUIREMENTS FOR THE BANDKNIFE MACHINE

The required design features of the bandknife machine could be grouped into two classes :

- (a) The physical size and shape limitations imposed on the design by the presence of existing structures.
- (b) The operational requirements of speed of blade, sharpening, and adjustments of blade positions.

It was necessary that the blade working length be sufficient to enable the largest skins to be processed. This meant that a working length of four feet was necessary.

The general plan of the MK I suction holding, raw skin shearing machine (shown in Figure 40, and described in Chapter IX) also influenced the frame design. The bandknife (A) in the figure was expected to be run in the inverted position shown. However, a range of possible positions of the blade, relative to the suction roller were required. Adjustment of the clearance between the blade and the suction roller (dimension (D) in Figure 41), and the angle between the blade and the tangent to the roller ((E) in Figure 41) were also required.

It was believed, as a result of the experiments carried out (see Chapter I), and from experience with the Kuris bandknife systems (Chapters, IV, V, VI) that a blade speed of 200 to 250 feet per second (12,000 to 15,000 feet per minute) was required.

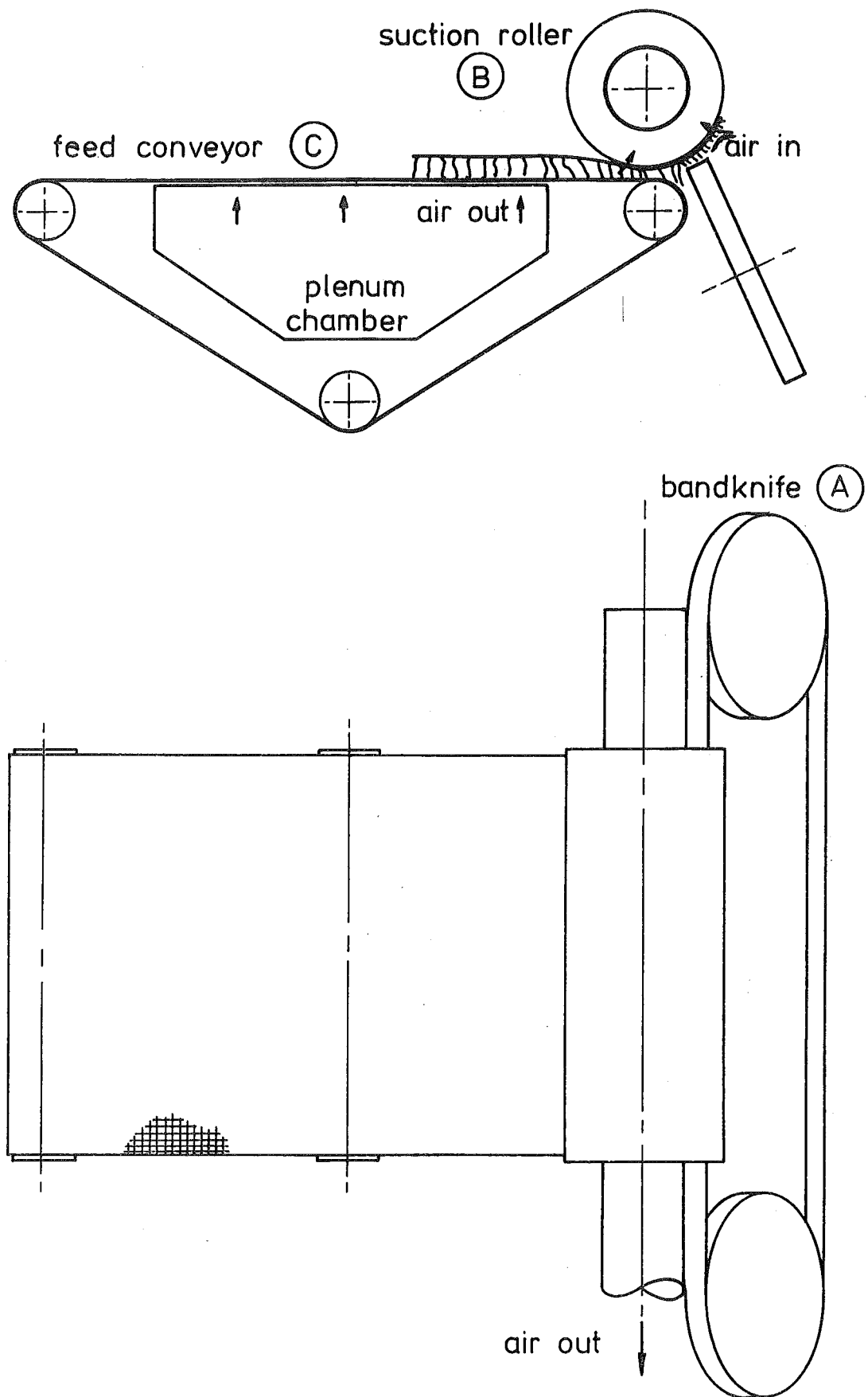


Fig 40 MARK I SUCTION ROLLER AND BANDKNIFE
MACHINE

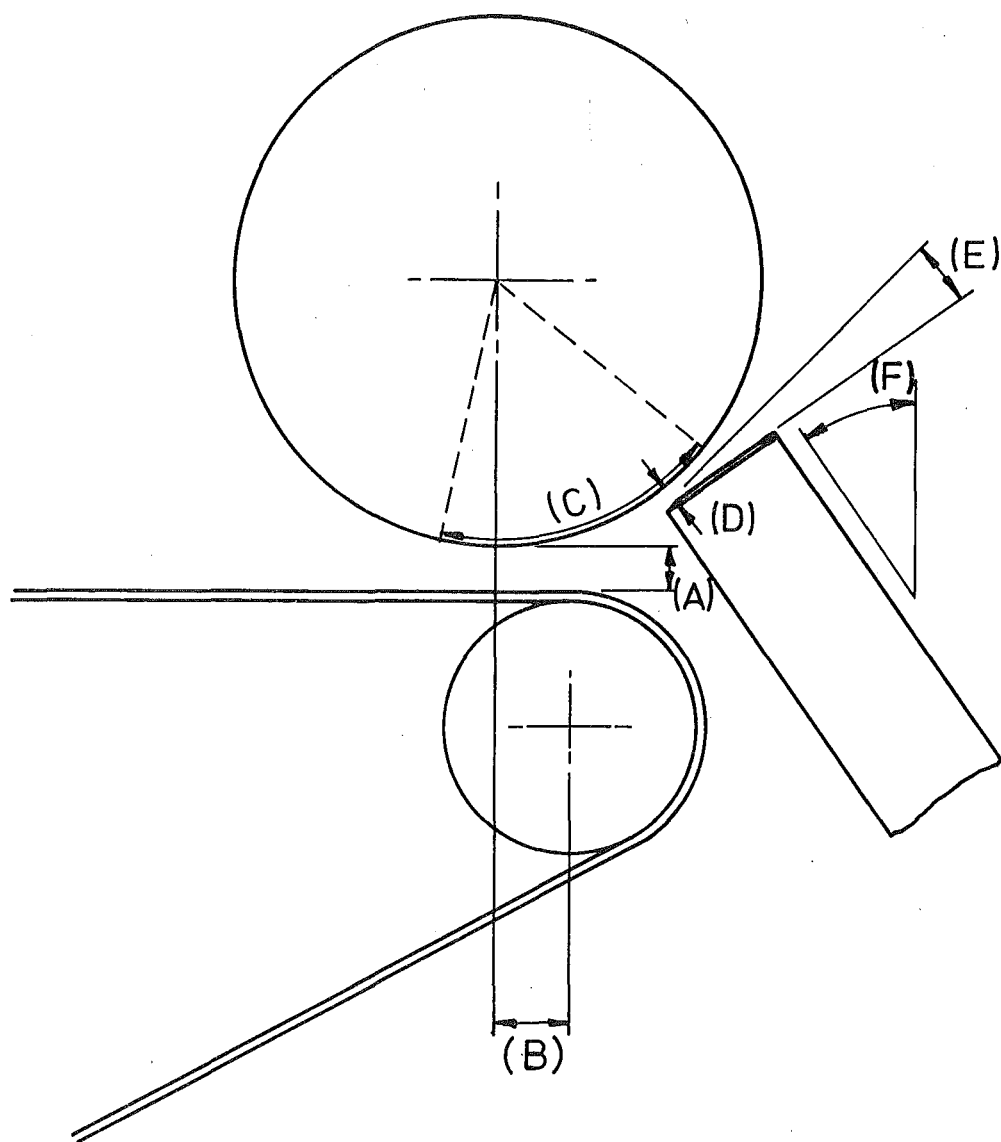


Fig 41 CLEARANCE DIAGRAM FOR MARK I MACHINE

These same investigations had shown that wool is an abrasive material to cut, and that frequent or continuous sharpening of the blade edge would be necessary.

VIII.2 CONSIDERATIONS OF COMMERCIAL BANDKNIFE EQUIPMENT

Before designing and constructing a bandknife machine to fulfil the above-mentioned requirements, a survey of commercial machines was carried out to determine their suitability for the task.

Many commercial machines are built for splitting solid materials like leather or plastic foam, and similar machines, with tooth-edged blades, are used for cutting metals, timber, etc.

In general, commercial bandknife machines are designed to run at speeds less than 85 feet per second (5,100 feet per minute) and are not designed to overspeed to 15,000 feet per minute in safety. All of the machines considered would have needed extensive modification to their basic structure, as well as strengthening for the dynamic loadings imposed, in order that the required adjustments of clearance, angle of attack and angular position would be possible.

The cost of buying a machine would have been about NZ\$15,000 - \$20,000. A costing for a locally built bandknife showed a \$1,000 material cost, and \$3,000 labour costs were to be expected.

On the basis of these considerations, it was decided to design and build a bandknife machine at the University of Canterbury.

The manufacturers, whose products were included in the survey, are listed in Appendix IV.

It should be noted that the decision to build a band-knife machine was taken during the initial design stages of the suction roller, and that the roller and the bandknife were designed together.

VIII.3 THE BANDKNIFE DESIGN

VIII.3.1 The Blade and Wheels.

A blade from a Rizzi splitting machine was used because knife technology is so far advanced that the construction of a blade was clearly impractical. This blade was 244" long, with a width of 2½" and a thickness of .056" (17 swg).

Design calculations (see Appendix V) showed that a wheel diameter of 26" was required if the band was to have an infinite fatigue life. (The original machine had 26" wheels, but further calculation showed that these, which were soft iron castings, were not safe at the speeds of the order of 2250 r.p.m., that were necessary to achieve a 250 feet per second blade speed.

Therefore, after calculations (Appendix V) showed that steel wheels were safe at these speeds, new wheels, fabricated from mild steel sections, were constructed. These wheels had a three inch wide flange, which was tapered towards the back-up ridge at the rear of the drive wheel, and was crowned on the take-up wheel.

The wheels were flange mounted onto cantilevered shafts, to facilitate blade removal.

VIII.3.2 The Main Frame.

The requirement that the wheels be cantilever mounted meant that the main structure of the bandknife frame was positioned behind the wheels. The stiffness of the structure was extremely important, because any deflection could cause the blade to leave its tracking position.

Welded steel fabrication was chosen as the construction method because :

- (a) it was a rapid system; and
- (b) this was a less expensive method than casting or forging large sections of the frame.

In order to facilitate rapid construction, many stock sections were used in the fabrication.

The frame is shown in Figure 42. It was decided to keep the area between the wheels (A) free, so a backbone type main frame was used. The main beam (B) (also sketched in cross section - Figure 43) incorporated a box to house the grinding wheels (C), and terminated at each end in diagonal beams, passing through the centre lines of each wheel, and carrying the bearing mounting (D) at the drive end and the adjustment slide (E) at the take-up end.

Bars (F) were bolted over the front of the wheels, to carry the tilt adjuster supports.

VIII.3.3 The Support System.

The central pipe of the suction roller was used to carry the bandknife machine. The support system is shown in Figure 44. Clamps (A) at each end of the machine gripped the pipe (B). The clamps carried the arm (C) which was mounted in bearings

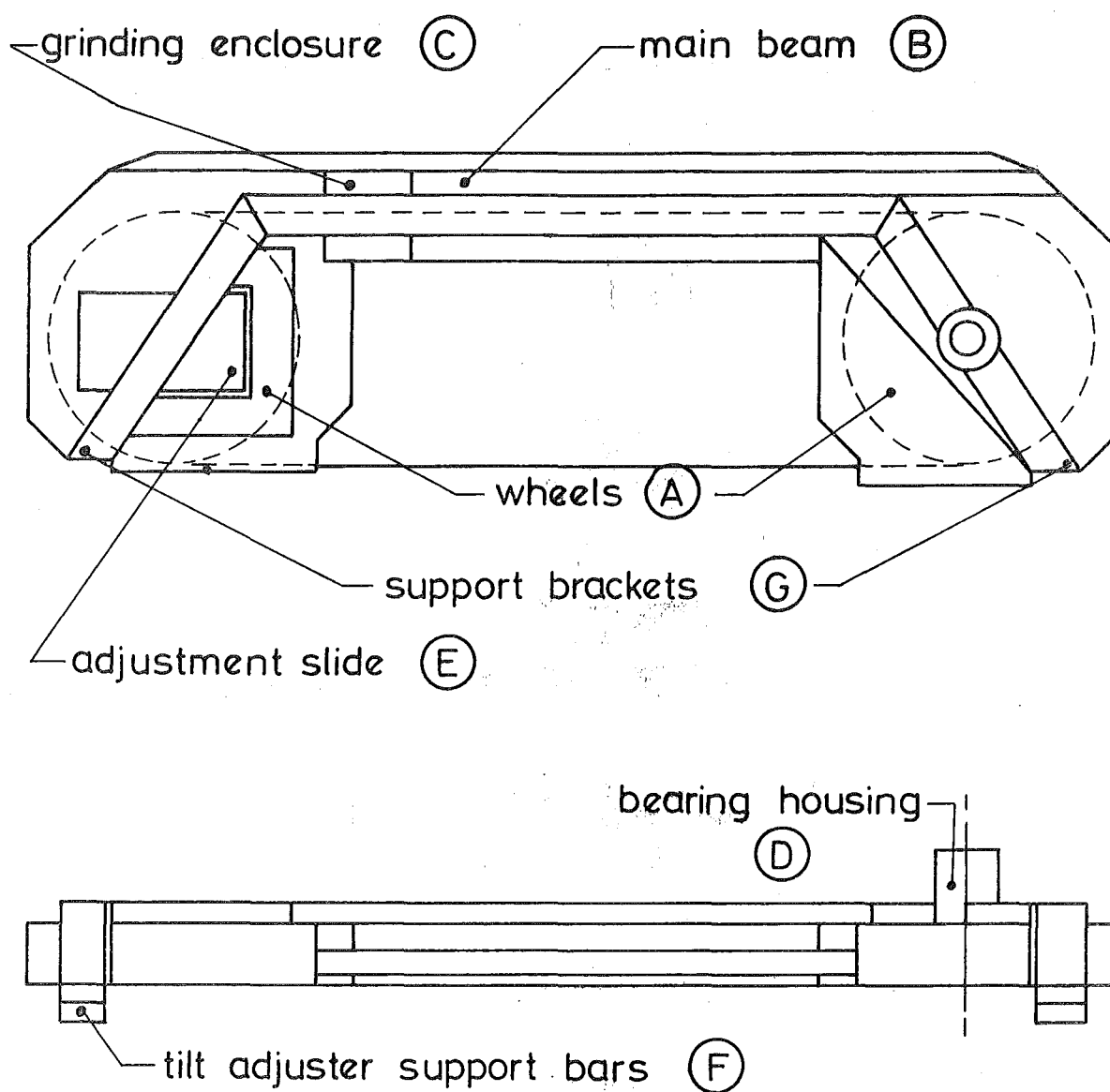


Fig 42 BANDKNIFE MACHINE FRAME

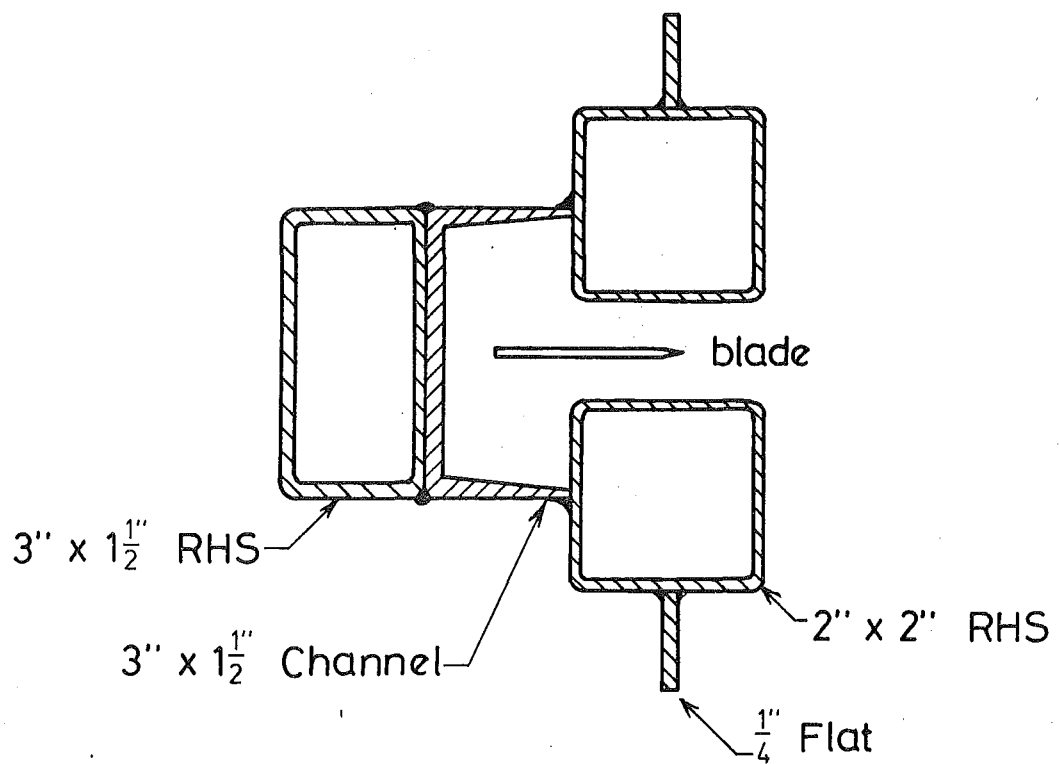


Fig 43 CROSS SECTION OF BANDKNIFE FRAME

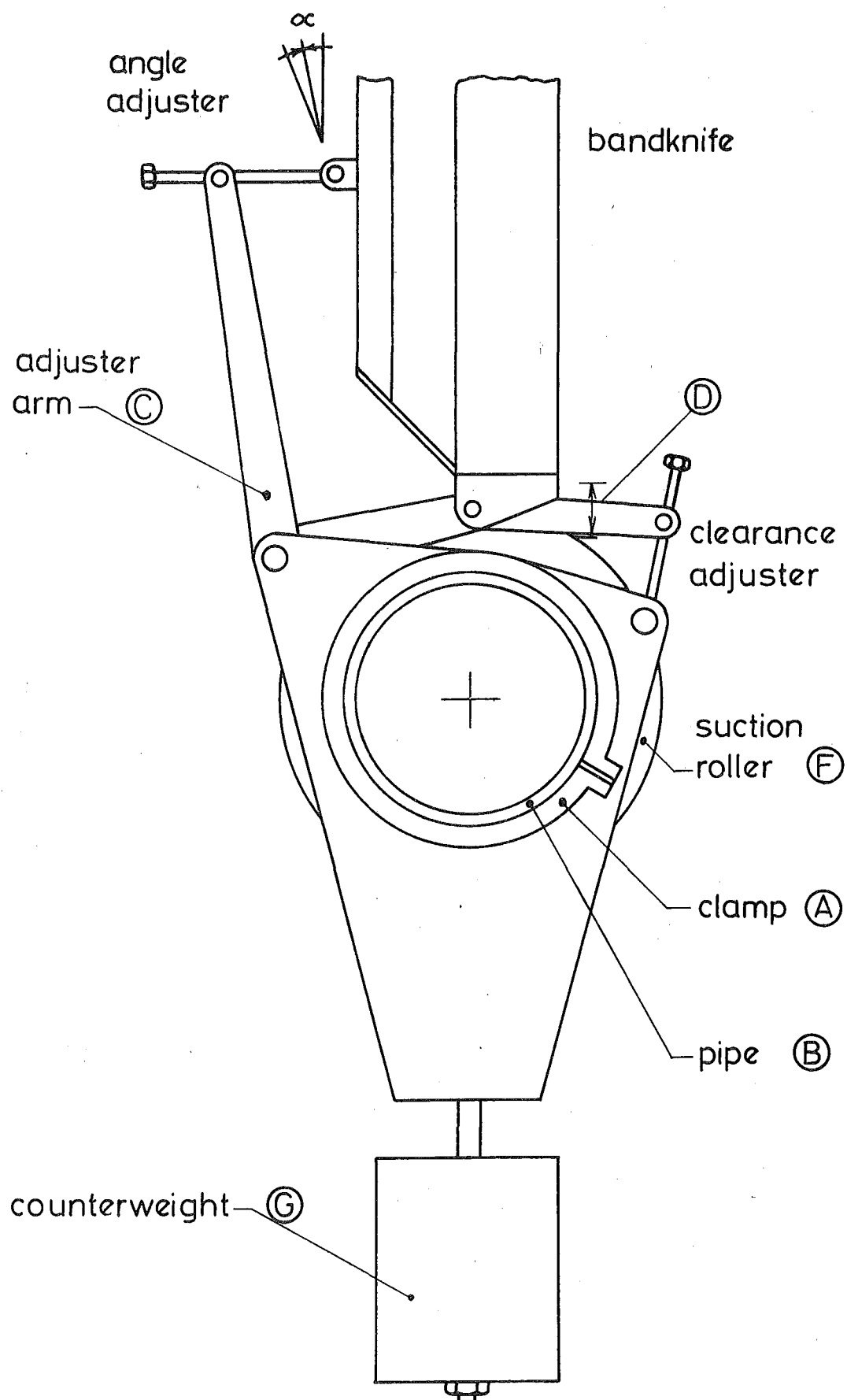


Fig 44 BANDKNIFE SUPPORT SYSTEM

at the elbow, and the horizontal section controlled the knife clearance (D) and the vertical section controlled the angle (α), both using screw thread adjusters.

The entire machine assembly could be rotated around the central pipe and thus around the suction roller (F).

Counterweights (G) were used to balance the weight of the bandknife during adjustment.

VIII.3.4 The Blade Sharpening System.

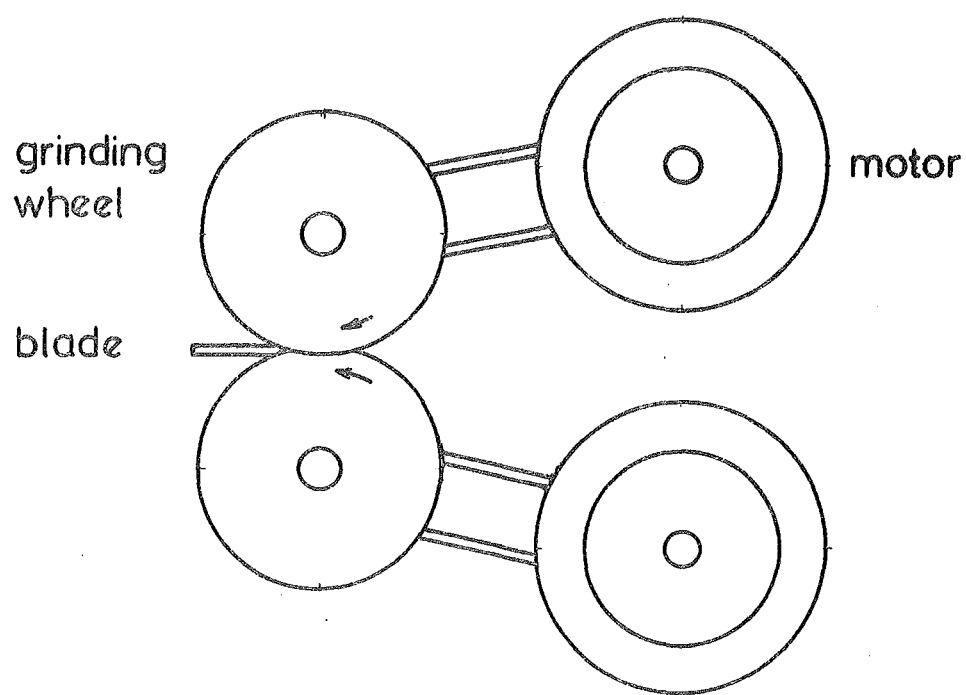
There were two clear choices of grinding system :

- (a) Parallel, vertical wheels, driven by an external drive (see Figure 45) and producing a hollow ground surface.
- (b) Inclined wheels, driven by the blade, again hollow grinding the edge, Figure 46.

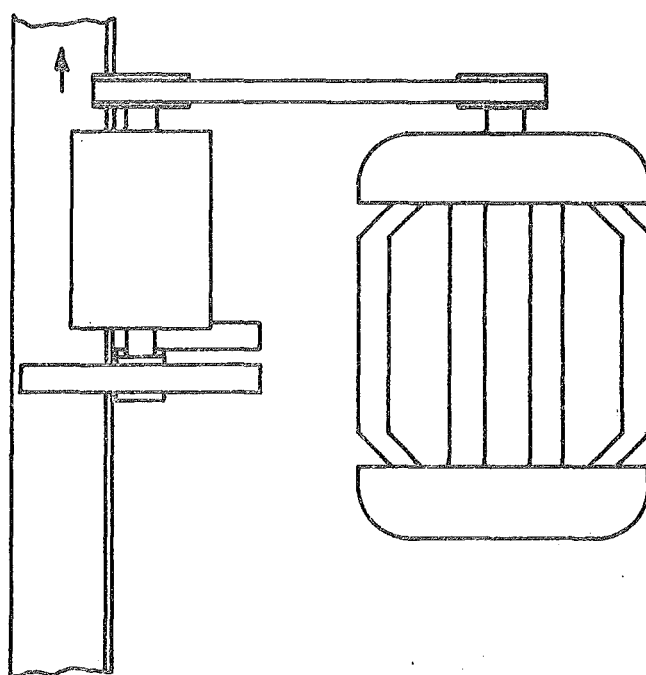
Following successful sharpening with the second system, on the Kuris machine, and to avoid the extra complication of driving the wheels, the self-energised system was used.

The wheel shafts were mounted in bearings, in housings which could be adjusted at right angles to the blade in the plane of the blade, and normal to the blade. The angles between the wheels and the vertical, and the wheels and the path of the blade, could also be altered.

The angle (α) in Figure 46 determined the grinding wheel speed, and the relative speed between the knife and the blade. Clearly at $\alpha = 0$, the wheel surface speed is the blade speed if there is no slip, while at $\alpha = 90^\circ$, the speed is zero, and the slip speed is the same as the blade speed. At $\alpha = 45^\circ$ the grinding speed and wheel surface speed are the



Elevation



Plan

Fig 45 PARALLEL WHEEL GRINDING SYSTEM

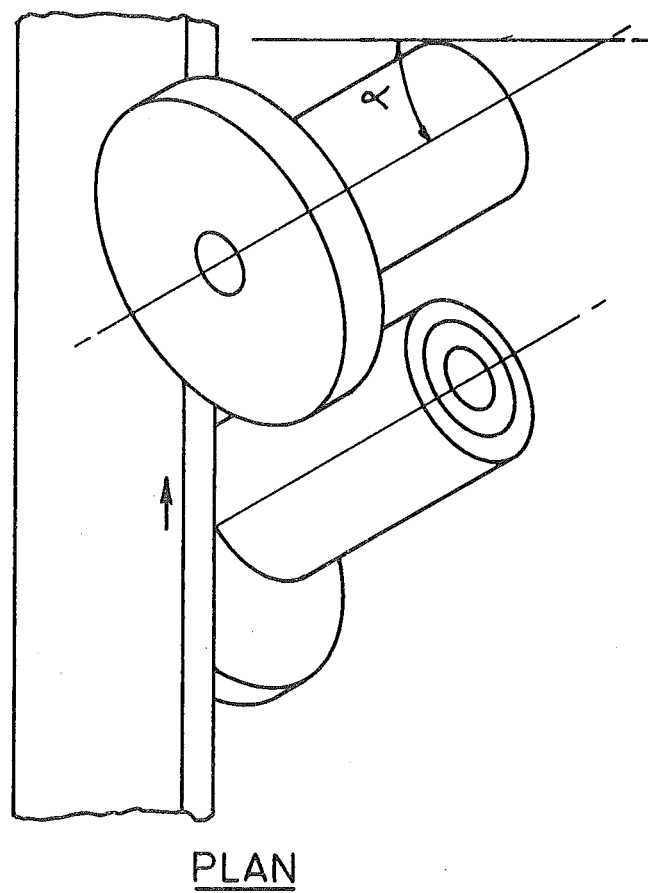
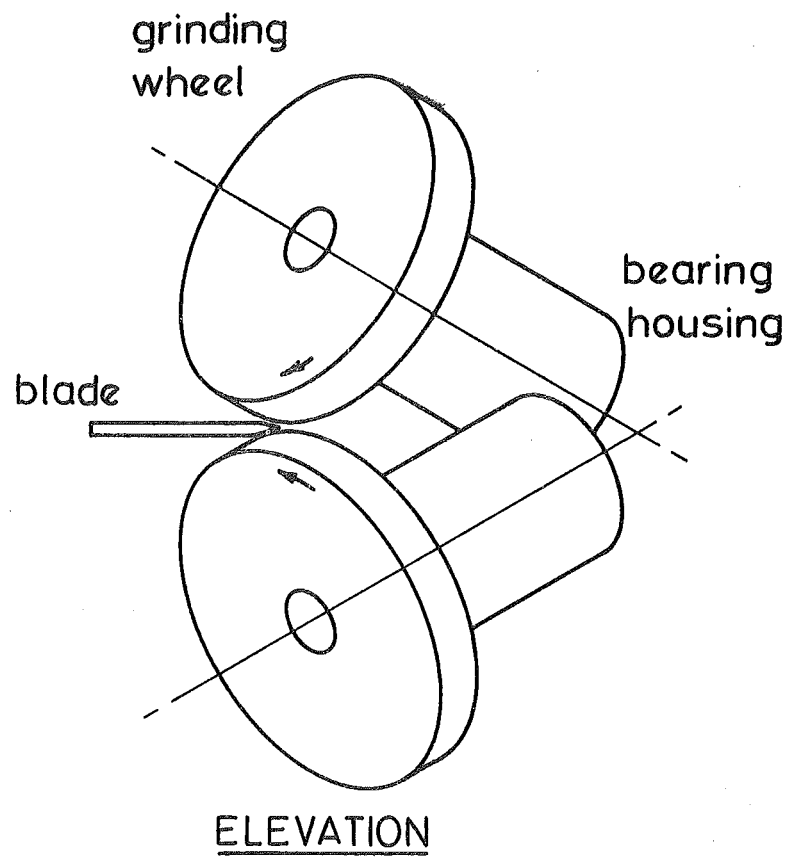


Fig 46 INCLINED WHEEL GRINDING SYSTEM

same. For example, at $\alpha=45^\circ$:

$$\begin{aligned} V_{\text{surface}} &= V_{\text{blade}} \cos 45 = V_b / \sqrt{2} \\ V_{\text{cut}} &= V_{\text{blade}} \sin 45 = V_b / \sqrt{2} \\ &= 250 / \sqrt{2} = 176 \text{ fps} \end{aligned}$$

Space limitations meant that wheels no larger than 4 inches diameter could be accommodated, thus giving :

$N = 10,000$ r.p.m. which was considerably in excess of the recommended speeds of 6,200 rpm for such wheels.

However, tests done in an enclosed chamber showed that a selection of four inch grinding wheels could be run at that speed without failure occurring. As the grinding mechanism was to be enclosed on the machine, and there being no alternatives to running at this speed, the system was retained.

The choice of grinding wheel was important to the success of the system. Several changes were made and these are described later in this chapter, in section 5.

VIII.3.5 General Design Features.

A five horsepower 2,850 r.p.m., three-phase induction motor drove the machine through three A-section vee belts. This system permitted speed alteration by changing of the drive ratio.

Thrust bearings (refer to Figure 29) were installed to prevent rearward movement of the blade during cutting. These were hard-faced ball thrust bearings of the type used in metal cutting bandsaws.

Felt scrapers were fitted to clean the blade and to prevent grinding dust, wool, etc. passing onto the wheels.

Apart from the working length of the blade, the entire bandknife machine was enclosed by guards.

The drive motor had overload protection, and emergency stop switches were positioned at two stations near the machine.

VIII.4 CONSTRUCTION AND INSTALLATION

Because of the fabricated construction methods used in making the frame, distortion caused by welding was a problem. Despite careful welding techniques some distortion of the main frame after completion was present, and this was minimised by bending in a hydraulic press.

The wheels were also of fabricated construction, and these were carefully welded to avoid distortion.

Following fabrication, the wheels were turned and carefully balanced.

There were no particular installation problems, and total construction and installation time was four months.

VIII.5 DEVELOPMENT OF THE BANDKNIFE MACHINE

VIII.5.1 Test Run Observations.

Initially, some difficulty was experienced in achieving blade tracking, but this was overcome by changes to the crown and taper angles on the wheels and by adjustment of the wheel angles.

Because of the high inertia of the system, and the high speed at which the blade was run, the time taken to run up to

speed was approximately 30 seconds, and the run down time was nearly two minutes. As continuous operation was envisaged, this was not a disadvantage, so no form of braking was considered necessary.

During sharpening, the blade tended to leave its tracking position, and move forward, causing a heavier cut and jamming to occur. The wheels had been arranged to counter-rotate in such a way as to push the blade away and a similar system had been used on the Kuris bandknife.

Two possible causes for this effect were :-

- (a) overheating of the ground edge; and
- (b) a frictional drag effect.

Because the sharpening was being carried out at higher speeds than were usual, the ground edge could have been raised to a high temperature, and the resultant thermal gradient across the blade would have caused uneven expansion. The more highly tensioned rear edge of the blade would have tended to climb the crown or taper, moving the blade forward on the take-up wheel and back on the drive wheel. As the grinding box was near the take-up wheel, less cooling could occur before the blade reached that wheel, and a movement on that wheel had more effect in the grinding area than a movement on the more distant drive wheel. Forward movement would have resulted in a greater heating effect due to heavier grinding and so the effect would be increased.

Measurement of the edge temperature while the blade was in motion was impractical, but measurements taken after grinding showed that no significant temperature gradient across the blade existed. A point contact probe was used in

conjunction with a digital readout system to measure the blade temperatures. A small increase in blade temperature (2 to 3 degrees Celsius) was observed after continuous running for some ten minutes or more.

Figure 47 is a representation of an imaginary thin grinding wheel being driven by a moving blade. It is clear that, in order to drive the wheel, the blade must exert a force F in the direction of wheel surface movement. This force has components F_A and F_B , F_B being reacted by the crowning effect. Consequently, the wheel must exert an equal and opposite force F_W which would tend to move the blade forward. Friction in the bearings and the wheel inertia contributed to this force.

It was felt that small temperature changes and small deflections in the bandknife frame during grinding were possibly contributing to the normal driving forces and causing the jamming.

From the alternatives of investigating the phenomenon more thoroughly, or changing the design to avoid the problem, it was decided that the design would be modified.

Further problems of rapid wear of the grinding wheels and poor ground surface finish were also experienced. This was partly caused by the non-availability of hard bonded, fine grit wheels in New Zealand. Initially, an A-60M wheel was used, but as this had an unacceptable wear rate, a harder bond was needed. Only an A-46P could be obtained and this exhibited a better life, but the coarser grit gave a rougher edge which was again unacceptable.

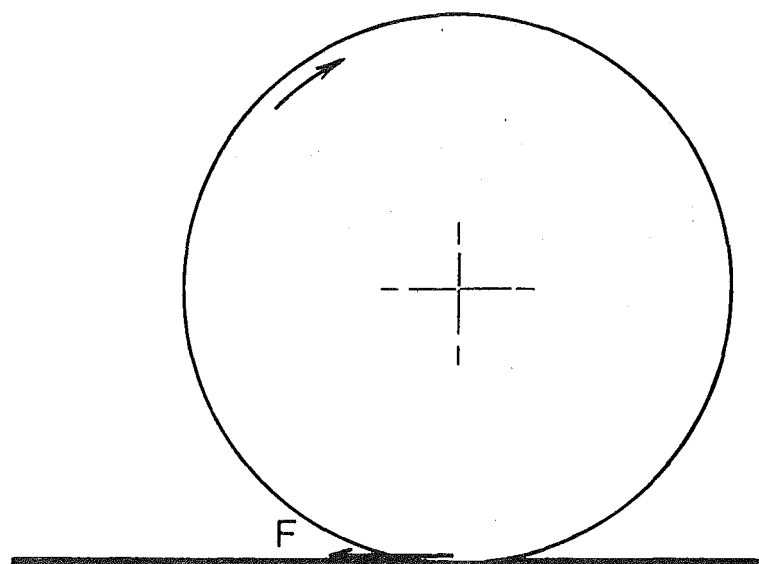
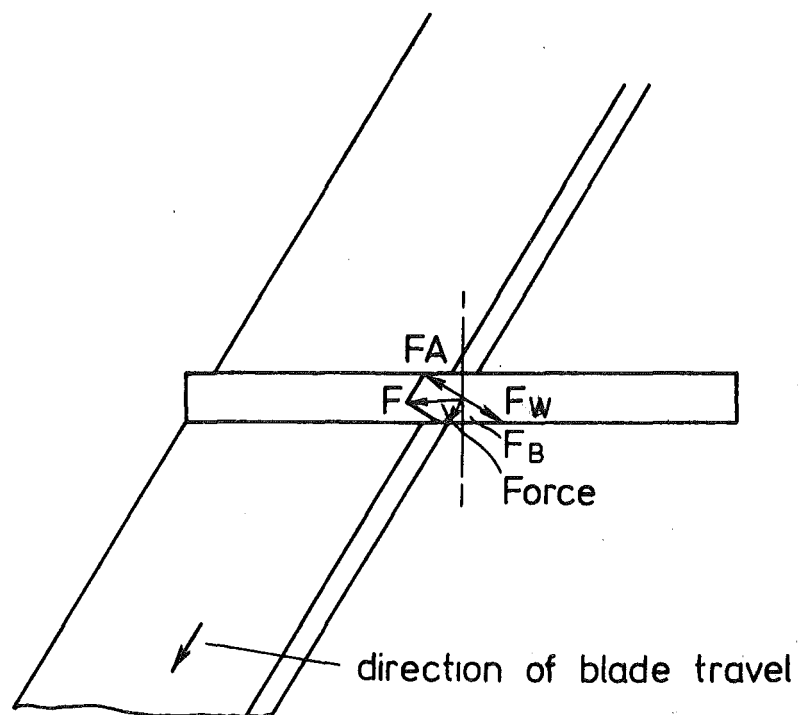


Fig 47 FORCES ON INCLINED GRINDING WHEEL

Grinding at lower speeds was more successful, both in terms of finish and wheel life, and in reduction of jamming problems.

Grinding wheel experts in Australia were consulted on the problem, and in general, their feeling was that a hard bonded, fine grit wheel would have produced the best results but that the grinding speed should be reduced if possible.

Grinding wheels of 100M and 220P grades were tried, but these gave only a small improvement.

At this time the author visited the United States of America, primarily to inspect bandknife machinery. American bandknife operators and manufacturers suggested that, provided the sharpening was carried out continuously, thus maintaining a very sharp edge, the blade speed could be reduced.

It was realised that high speeds were necessary only when intermittent sharpening was employed. In effect, this was an example of the law of diminishing returns: the faster the blade moved, the less efficient was the sharpening, and the blade speed was required to be increased.

VIII.5.2 Modifications Made to the Machine.

Therefore, two changes were made to the machine :

- (a) The blade speed was reduced to 90 feet per second (5,400 f.p.m.) This was done by replacing the 2,850 r.p.m. 5 H.P. motor with a 5.5 H.P., 1,410 r.p.m., 3-phase induction motor. This drove the machine via a triple A-section belt drive with a step down ratio of 1.75:1.

- (b) The grinding apparatus was modified so that the grinding wheels were mounted parallel to each other, and with their axes parallel to the line of blade movement. (See Figure 45). A 3,000 r.p.m. (maximum) 3/4 H.P. air motor drove the wheels, through round belts.

VIII.5.3 Further Test Runs.

Tests carried out with the modified bandknife machine showed that, as far as could be seen from the performance of the cutting machine as a whole (and this was still under development itself, refer Chapter IX), the cutting action of the bandknife machine was at least as good as before.

The problems of jamming and excessive wear of the grinding wheels were overcome with these design changes. The positively driven, counter-rotating wheels tended to push the blade away, if there was still any tendency for the blade to move.

The finish imparted by the grinding wheels, and the sharpness of the edge, as demonstrated qualitatively by feeling with the hands, were both improved.

It was expected that the life of the blade would be shortened by continuous grinding, but the economics of the project suggested that, provided the machine could run for eight hours without a blade change, it would be acceptable. Only long term testing of a successful machine could provide an answer.

It was observed that the increase in stubble length along the direction of cutting was, once again, present. Previously

this had been caused by :

- (a) blade deflection; and
- (b) backing material compression.

In this case, because the backing material was the rigid suction roller, the cause was probably blade deflection, but there was also the possibility of the wool fleece compressing as the blade rode over the stubble.

However, it was decided that a blade guide, of the same form as that described in Chapter VI, would be constructed.

The blade guide reduced the stubble length variation and it was assumed that the remaining variations were due to compression of the wool. This was the subject of further investigation in the MK II machine (See Chapter IX).

VIII.5.4 Further Design Modifications.

A plane slotted blade guide was fitted to a short (6 inch) length of blade in the grinding area. This served to prevent the offset grinding wheels twisting the blade, as it passed through them.

Referring to Figure 48, in addition to the plain slotted guide, (A), a back-up block (B) was controlled by a screw and locknut (C). This adjustable block was intended to prevent rearward movement of the blade under load.

Felt scrapers were also placed at the end of the grinding box and at the end of the cutting area, to prevent build-up of grindings, etc. on the wheels.

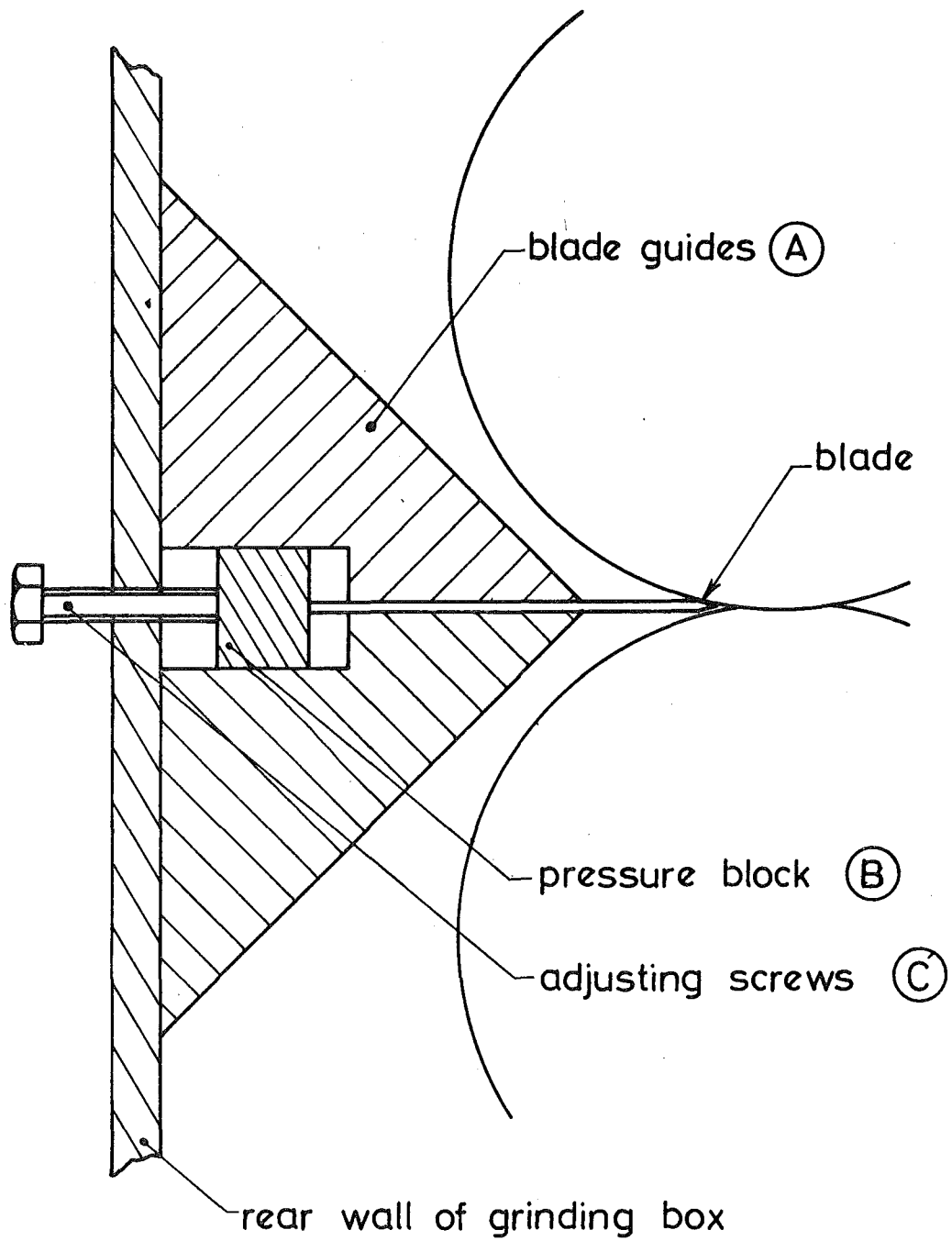


Fig 48 BLADE SUPPORT IN GRINDING AREA

VIII.6 SUMMARY OF BANDKNIFE MACHINE DEVELOPMENT AND
PERFORMANCE.

The bandknife machine performance could obviously only be assessed as a component in a more complex system. That is, the other components of the raw skin shearing machine all influence each other's performance.

Some problems could be isolated, such as the tracking and jamming problems. Therefore, the bandknife machine itself had been developed to the stage where it would perform as any commercially available bandknife machine would have done.

Further problems, which were considered unique to wool cutting machines, were experienced in the operation of the bandknife shearing machines, and these are described in Chapter IX.

CHAPTER IX

THE SUCTION HOLDING, SKIN SHEARING MACHINES

IX.1 THE MARK I SUCTION ROLLER AND BANDKNIFE MACHINE

IX.1.1 Objectives of the Machine.

It was hoped that this machine would satisfactorily cut wool from raw woolly skins and that investigations of the important parameters of continuous shearing, such as blade life and cleaning of the machine, could be carried out.

IX.1.2 The Overall Machine Concept. The Mark I machine consisted of three major sub-assemblies. Referring to Figure 40, these were :-

- (a) a bandknife machine, (A), described in Chapter VIII. At the time of building the Mark I machine, the bandknife was in the early stages of development, and had the original self-energised grinding system, and a blade speed of 250 feet per second;
- (b) a suction roller (B), described in Chapter VII;
- (c) a feed-in conveyor system (C), which had previously been an experimental skin spreading machine.

The bandknife machine was mounted in an inverted position, to cut close to the suction roller, following skin pick-up from the conveyor. The suction roller was positioned above the drive roller of the feed conveyor.

IX.1.3 The Feed-in System.

Although not designed by the author, the feed-in system conveyor was part of two parallel development projects carried

out by final year Mechanical Engineering students. The aim of these projects was the automatic spreading of raw sheep-skins prior to cutting. The machine, represented by Figure 49, was designed by Winn and Dixon² and developed to the stage described here by Gillespie³. A wire mesh conveyor belt (A) passed around three rollers (B) enclosing a plenum chamber (C). The plenum chamber was an open topped box with a centrifugal fan (D) discharging into one side. Adjustable baffles (E) directed the flow upwards through the belt.

When a skin, with the wool side facing the belt, was carried across the top of the plenum chamber, the airstream tended to lift the woolly skin. Suitably angled air jets (F) were arranged to discharge on the flesh side, smoothing out the wrinkles and folds in the skin.

Although the system had some success, and the need for further development was indicated, spreading was done by hand in the shearing process, to ensure a fold-free skin. However, the conveyor feed-in system was still a necessary part of the machine.

IX.2 PERFORMANCE OF THE MARK I SHEARING MACHINE

IX.2.1 Built-in Adjustments.

As already described in Chapters VII and VIII, there were a number of adjustments of clearances and positions, the correct adjustment of which was expected to be important.

Figure 41 is a clearance diagram for the machine used for defining the following notation :-

(A) was the clearance between the suction roller and the feed conveyor, adjusted by moving the roller upward and downward.

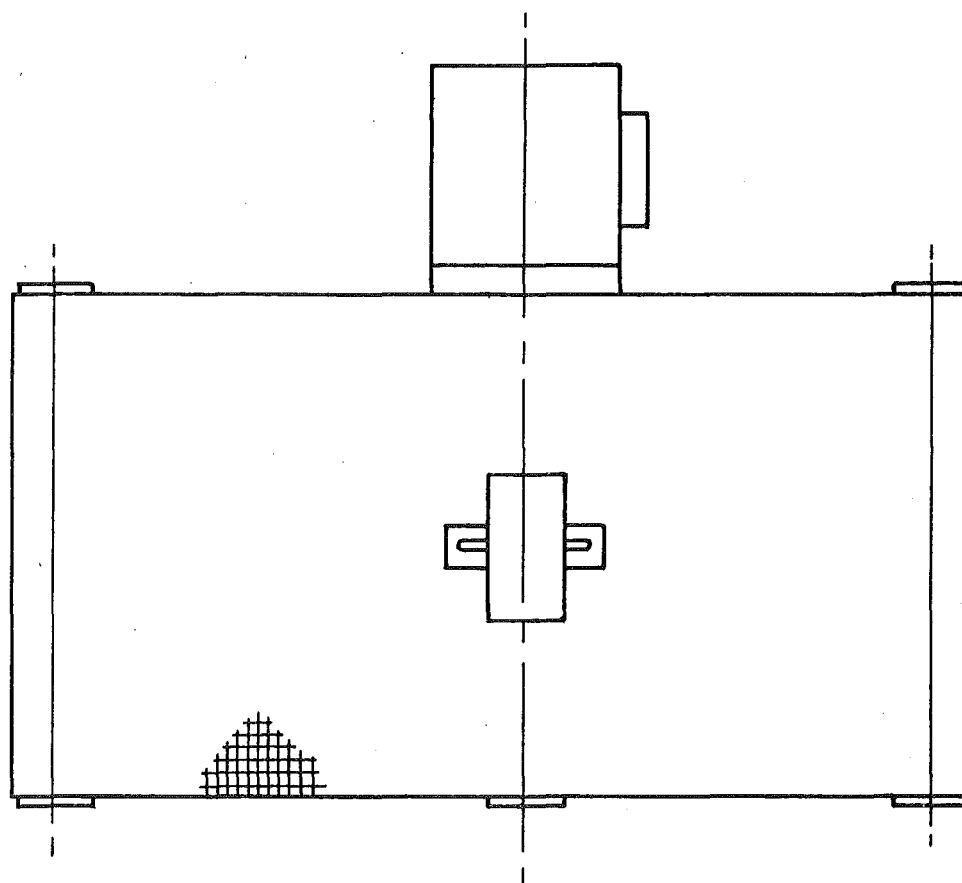
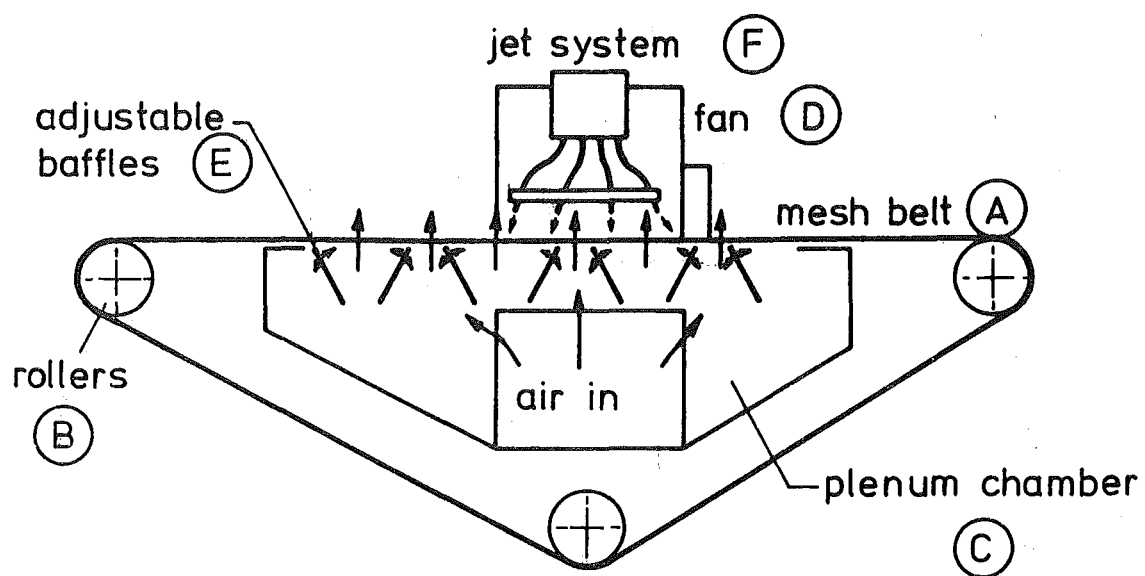


Fig 49 SKIN SPREADING CONVEYOR

(B) was the horizontal distance between vertical projections of the suction roller and conveyor drive roller centres. This was altered by moving the suction roller adjustment slides back or forward.

(C) was the distance around the circumference of the roller over which suction was applied. The internal roller baffles controlled this parameter.

(D) was the clearance between the bandknife blade and the suction roller at the closest point. This was adjusted by moving the vertical adjustment frame screws (C) in Figure 44.

(E) was the angle between the plane of the blade and a tangent to the roller through the point of minimum clearance. This was adjusted by the bandknife tilt adjuster (E) in Figure 44.

(F) was the angle the bandknife machine as a whole made with the vertical, and was adjusted by rotating the entire bandknife frame about the suction roller.

IX.2.2 Test Run Conditions.

The settings of some of the built-in adjustments were determined by experiment during construction. The clearance (A) was set up during suction tests and (B) was arbitrary.

Distance (C) was set at eight inches, a figure determined by the amount of area needed for the bandknife to be surrounded by a holding area. (F) was the minimum convenient angle at which the bandknife machine frame could be set.

(D) and (E) were to be the subject of experimentation.

The skins used were from recently slaughtered crossbred ewes. These were preserved for short periods in a home freezing unit. Wool length varied from about two inches to four inches. In order to unfreeze the skins, they were soaked in water, then centrifuged dry.

The skins consequently closely resembled those at a typical freezing works, including the moisture content.

The speed at which the skins were fed in was variable from four to sixteen inches per second and initially a feed-in speed of nine inches per second was used. The suction roller surface speed was varied accordingly (see Chapter IX. 2.4, IX.4.6.)

IX.2.3 Description of a Typical Test Run.

In general, the test runs followed the same pattern. After setting or resetting any of the variables (A) to (E), the bandknife was started and sharpening carried out. Then the suction fan was run up to speed and the suction roller drive started.

The skin was laid, wool side down, on the feed-in conveyor, folds and wrinkles having been removed, and the legs trimmed. The feed-in conveyor was then started and, after the skin had passed through the machine, the wool and pelt were inspected and, in some cases, preserved.

In all, some three dozen skins were passed through the machine during the initial test runs.

IX.2.4 Initial Test Run Results.

The test runs with this machine were more successful than those with the earlier bandknife machines, in that jamming of the system did not occur. However, the criteria of no damage to the skin and short stubble were not reliably met.

The most common fault was a failure to cut evenly. There was a tendency for the stubble length to increase as the cut proceeded. (See Chapter VIII, Section 5.3). Damage

to the skin was not observed as often as before, but when the blade was angled downwards with respect to the skin, in an effort to produce even cutting, damage was more common.

Some useful information was obtained. It was found that running the suction roller at a surface speed some five to ten percent faster than the conveyor, had the effect of smoothing the skin surface and reducing wrinkling on pick-up. (See also IX.4.6).

The skin often tended to stick to the suction roller after cutting. When this occurred, the skin was then carried round by the roller until it overlapped with the incoming skin. This invariably resulted in damage to the pelt.

On some runs the wool bent away from the blade edge and was not cut at all, merely passing under the blade. While it was felt that insufficient blade sharpness contributed to this, it was clear that the fibres needed some form of support.

When the blade clearance was reduced this effect was lessened because the cut was being made closer to the wool roots.

IX.2.5 Modifications.

As described in Chapter VIII, Section 5.3, a blade guide was fitted to the bandknife in an attempt to produce an even stubble length. However, this did not eliminate the problem, and the extra drag on the blade caused the bandknife drive motor to overheat. As other modifications to the bandknife (as described in VIII5) were contemplated, this was not corrected at this stage.

In order to prevent pelts attaching themselves to the

roller, a scraper (A) in Figure 50 was fitted to the suction roller. To prevent pelts falling back into the cutting area, a roller (B) in Figure 50, was installed. This was driven at a slightly greater speed than the suction roller, to further aid the stretching effect.

During the series of test runs, the bandknife was the subject of modifications. These were of a minor nature (changing grinding wheel grades etc., described in Chapter VIII).

IX.2.6 Further Test Runs.

The sticking of the skin to the roller was reduced by the addition of the roller scraper, but the overall performance of the machine was not markedly improved by these modifications. Although a small number of skins were shorn in a satisfactory manner, there were many more cuts which were unsatisfactory because of stubble length variation and/or failure to cut.

IX.3 THE MARK 2 SUCTION ROLLER AND BANDKNIFE MACHINE

IX.3.1 The Machine Concept.

The testing of the Mark I machine had shown that satisfactory cutting of the fibres from the skin was not being achieved.

In the Mark 2 version the modified bandknife machine (see Chapter VIII, section 5.2) was used, and a new feed-in system was designed. This also provided for fibre support during cutting and wool removal following this.

IX.3.2 The Feed-in System.

Although similar in concept to the original conveyor

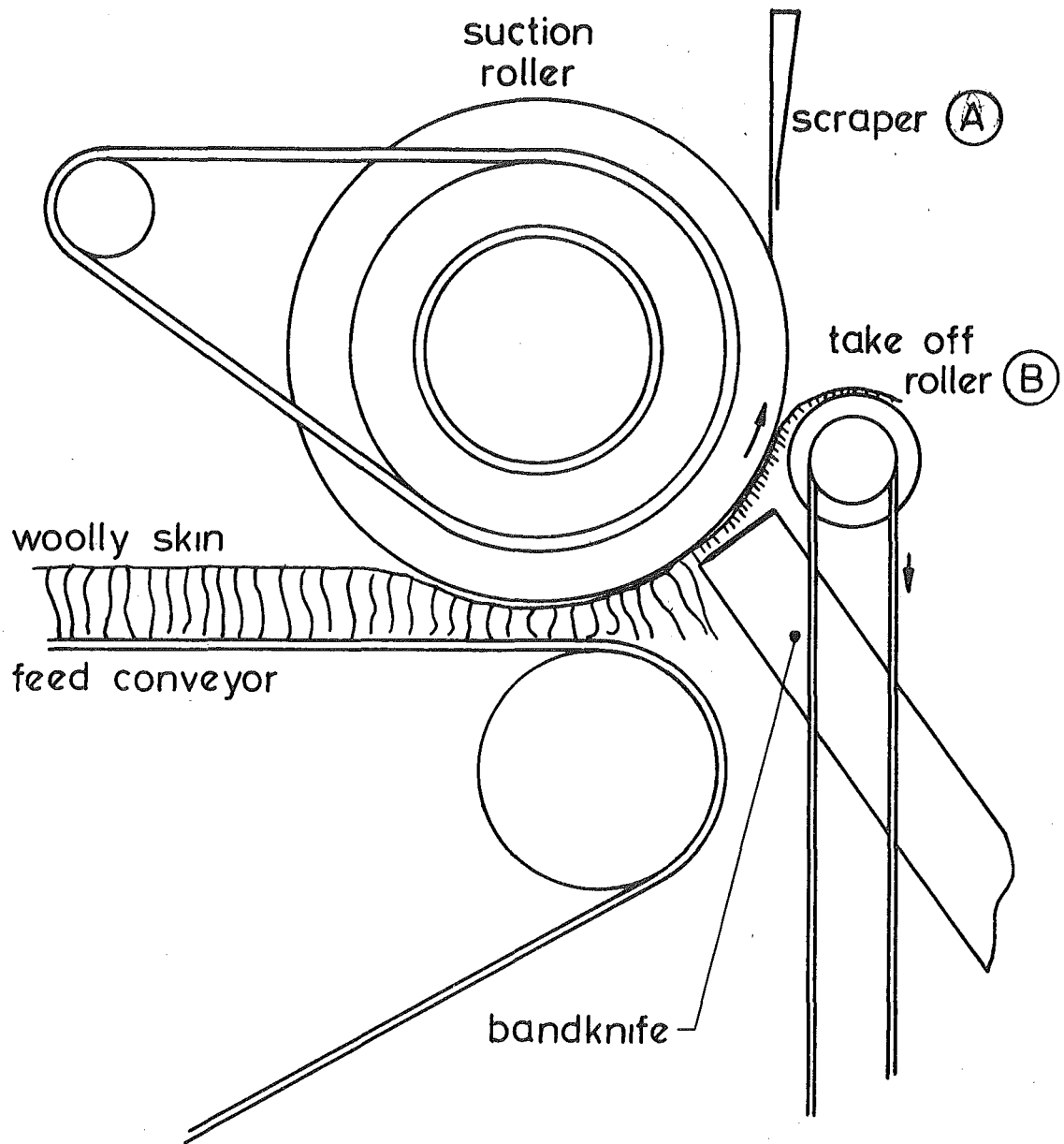


Fig 50 SCRAPER AND TAKE OFF ROLLER ON THE
MARK I MACHINE

system, the Mark 2 conveyor was a completely new unit. The width of the wire mesh belt, and frame and rollers, was reduced to allow the conveyor to pass between the upper and lower bandknife blade runs.

The Mark 2 system is shown in Figure 51. The wire mesh conveyor belt (A) moved around the rollers (B) and over a plenum chamber (C). The plenum chamber, which was supplied with air from a centrifugal fan (D) had only one opening, directly beneath the suction roller (E). A removable contraction (F) directed the air flow towards the blade, through the belt, thus bending the fibres over the blade edge.

After cutting, the fibres were carried by this air flow past the blade guide (F) and were directed back onto the conveyor by the duct (G).

In its final form, the pelt take-off roller (H) was intended to be part of a conveyor system.

IX.4 PERFORMANCE OF THE MARK 2 SHEARING MACHINE

IX.4.1 Test Conditions.

In general there was no difference in type of skin, operating speed or variation of the adjustments described in Section 2.2 of this chapter, except that the angle the bandknife machine made with the vertical was decreased from 35° to 28° . This was not an essential change, but the additional space now available allowed this, and the take-off roller also, was lowered. This meant that the skin was carried by the suction roller further past the take-off roller than before, ensuring the skin did not fall before the roller could remove it. (The same effect could have been

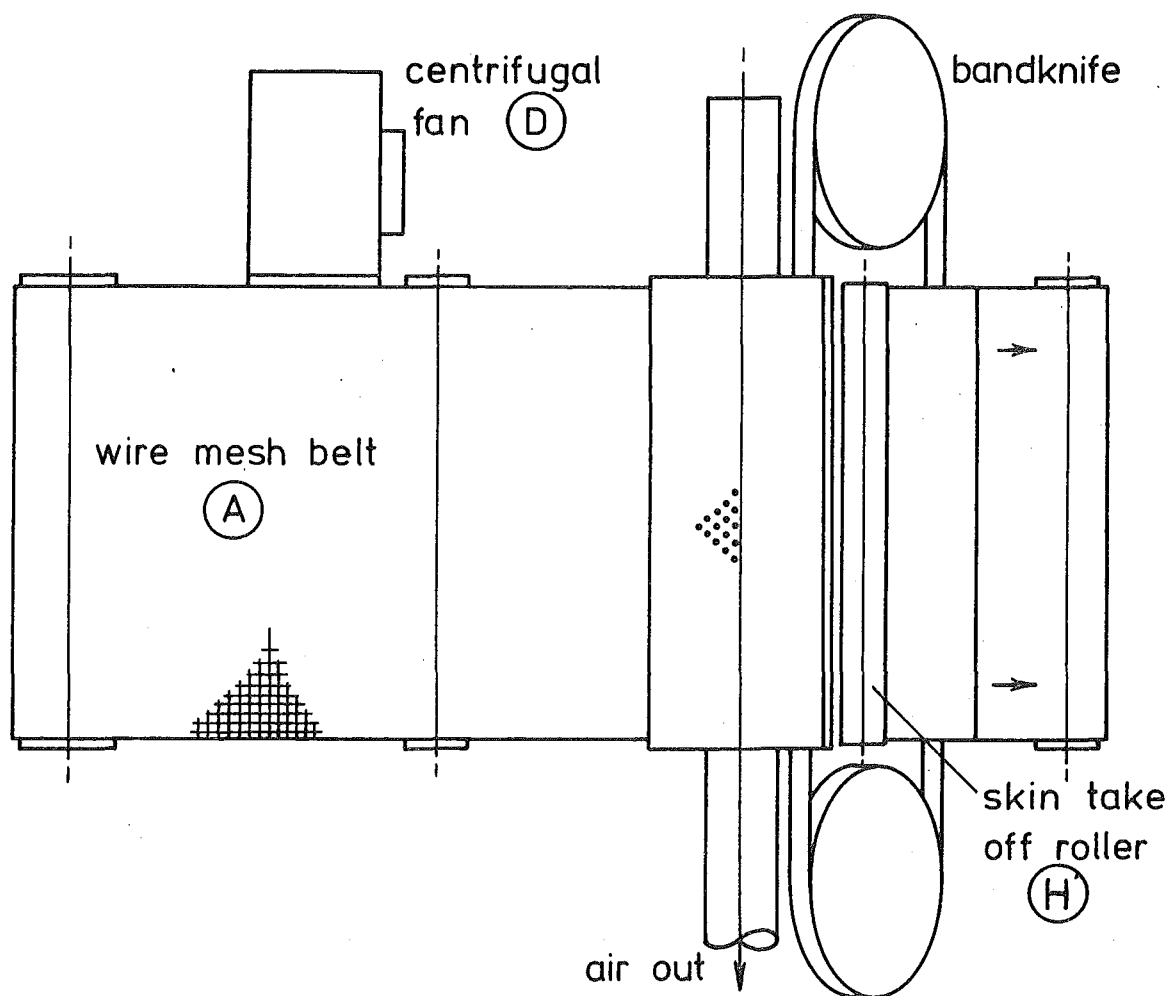
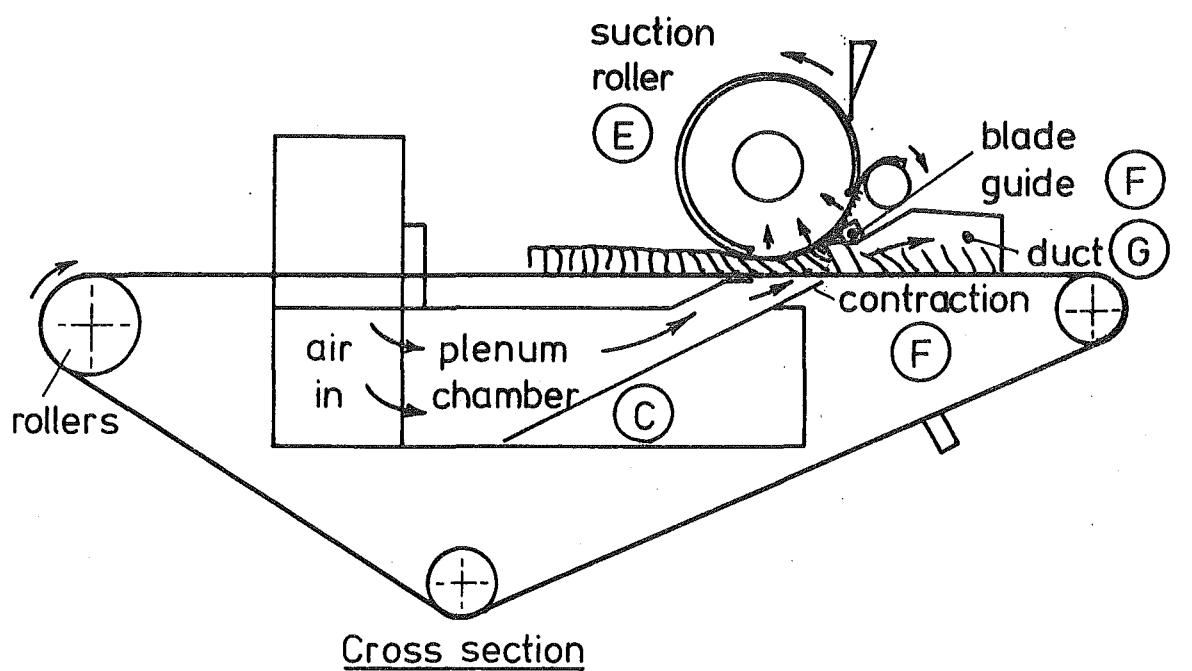


Fig 51 MARK II SUCTION ROLLER SHEARING MACHINE

achieved by modifying the internal baffles of the suction roller, but this would have caused a decrease in pressure drop across the surface).

IX.4.2 Test Run Results.

Initially adjustments were made to the internal baffling of the plenum chamber (C) in Figure 51, and the contraction (F) in order to achieve a flow across the blade, and to avoid backflow along the conveyor. Smoke tests were used to observe the flow.

It was necessary to restrict the output of the centrifugal fan (D) because too large a flow past the blade would have broken up the fleece. An adjustable baffle on the fan inlet was used to do this.

The first skins processed were damaged by the blade, even with the blade half an inch from the roller. Observation of the progress of a skin through the machine indicated that the take-off roller, whose drive system had been changed from belt drive to friction drive from the suction roller, was stalling, and causing wrinkling in the cutting region.

It was decided, therefore, to install a new drive system for this roller and in order to prevent any possible detachment of the skin before the roller was reached, it was decided to further lower the roller relative to the suction area.

Provided the air flow from the plenum chamber was reduced for short wool lengths, the cut fleece emerged intact from the machine.

IX.4.3 Modifications to Skin Removal Roller.

As the wool removal roller rotated in the opposite

direction to the suction roller, a crossed round belt (A) in Figure 52, which ran on the flange between the suction roller and the suction roller drive sprockets, turned the drive pulley (B). The removal roller ran with a surface speed five percent greater than the suction roller surface to provide a stretching effect.

This roller had a scraper (C) in Figure 52 to remove the skin. As both this and the suction roller scraper had shown a tendency to jam, rubber rings (D) were glued onto the roller, and cutaways were provided in the scraper to clear these. This was done to prevent the skin resting on one flat surface, making unpeeling less difficult. The roller is illustrated in Figure 52.

The duct (shown as (A) in Figure 53) was modified to allow the removal roller to be lowered. A modified bearing support system for the roller was also constructed.

IX.4.4 Further Test Runs.

An improvement in the condition of the cut skins was noticed in that the frequency of damage was reduced and in most of those cases the extent of damage was less. Some folding and wrinkling under the blade was apparently still occurring, and it was thought that the rubbing of the skin on the lower blade guide was causing this.

During these tests the blade suddenly seized in the guide. Inspection of the guide surfaces revealed a build-up of a black, tar-like matter. There had been no sign of seizure with earlier blade guides, but this Mark 2 machine had a continuous sharpening system and greater quantities of grinding dust were evident in the grinding enclosure than had been

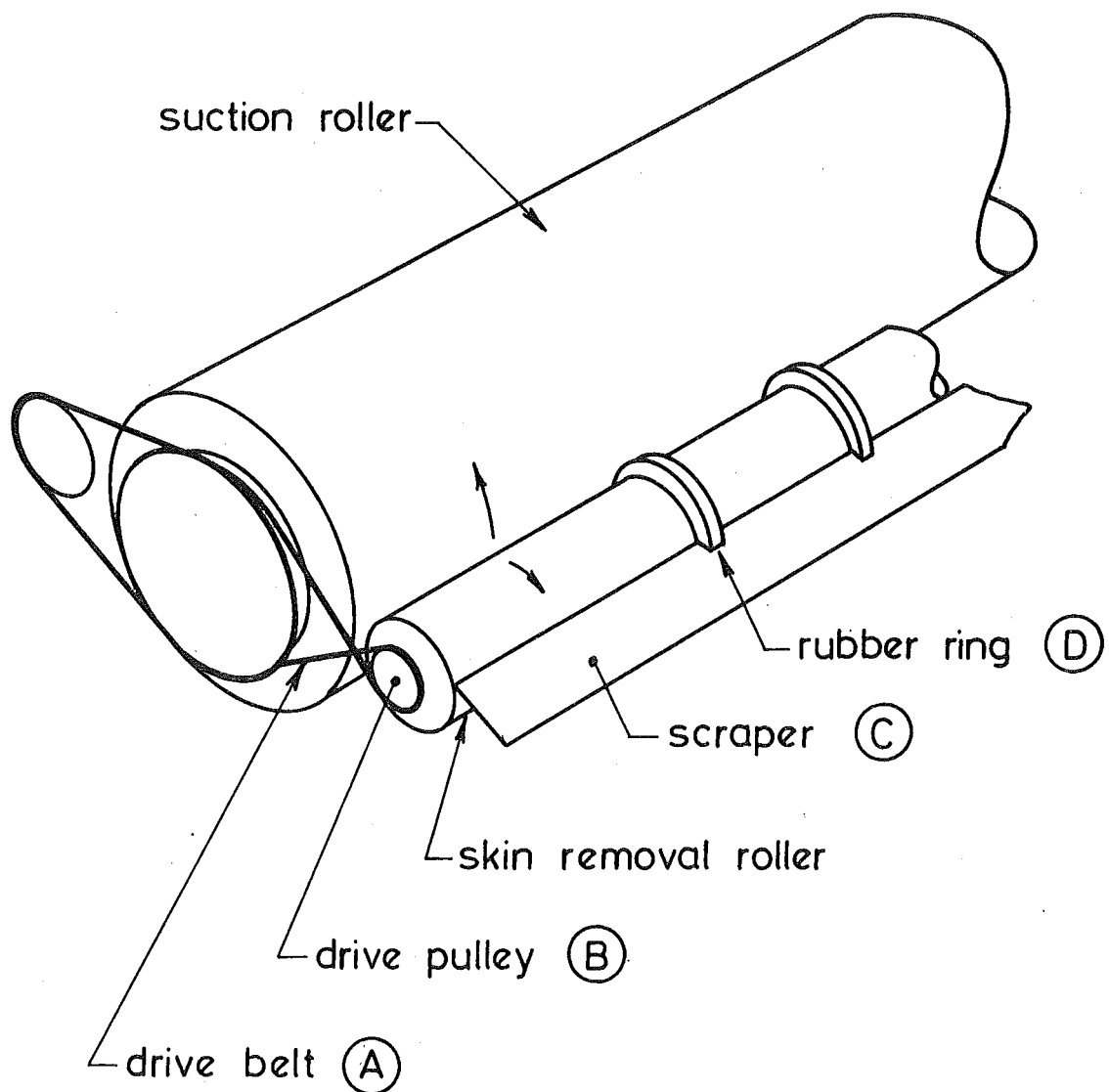


Fig 52 SKIN REMOVAL ROLLER

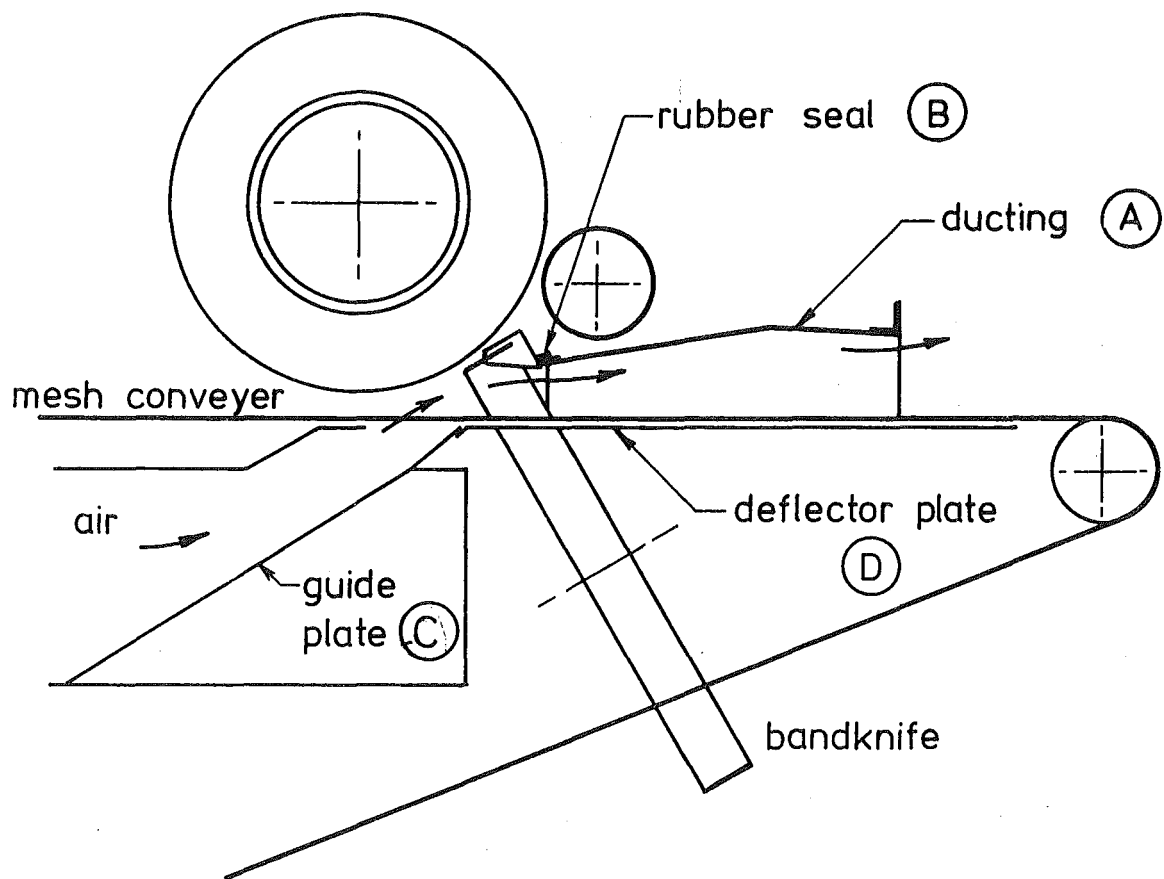


Fig 53 DETAILS OF THE WOOL HANDLING SYSTEM

present in the Mark I machine. It was assumed the deposits in the guide were a combination of dust and grease from the wool.

It was found that kerosene readily removed the deposits and it was decided that a kerosene oiler would be installed, and other changes made to the guide while it was dismantled.

IX.4.5 Modifications to the Blade Guide.

Three operations were carried out on the blade guide :

- (a) A pair of kerosene-lubricated, felt wiper pads (A) in Figure 54, were installed at the entry of the blade guide.
- (b) In order to provide further thrust capability, back-up bearings (B) in Figure 54 were installed at each end of the guide. These were ball races arranged to run in contact with the blade when it was loaded. Unlike the original thrust bearings (Figure 29), there was no sliding contact, as this had been found to cause overheating of the bearings.
- (c) The lower blade guide was machined to the shape shown in Figure 55. With less material under the blade, and a sharper profile, less resistance to skin movement was expected. Material was also removed from the upper blade guide to lower flow resistance in the duct.

IX.4.6 Further Test Runs.

With kerosene lubrication no further seizure problems were experienced even after protracted testing.

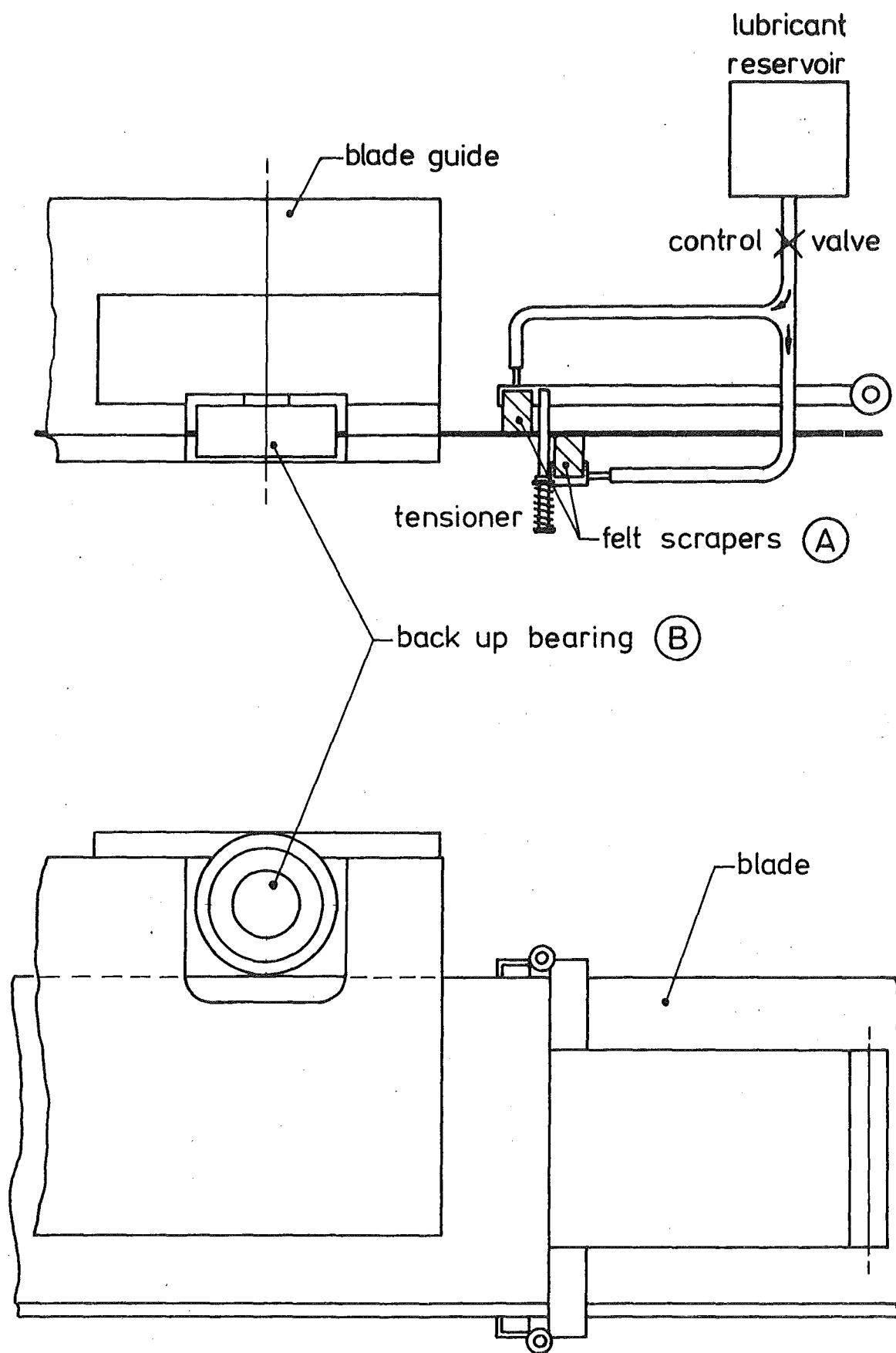


Fig 54 BACK UP BEARING AND LUBRICATION SYSTEM

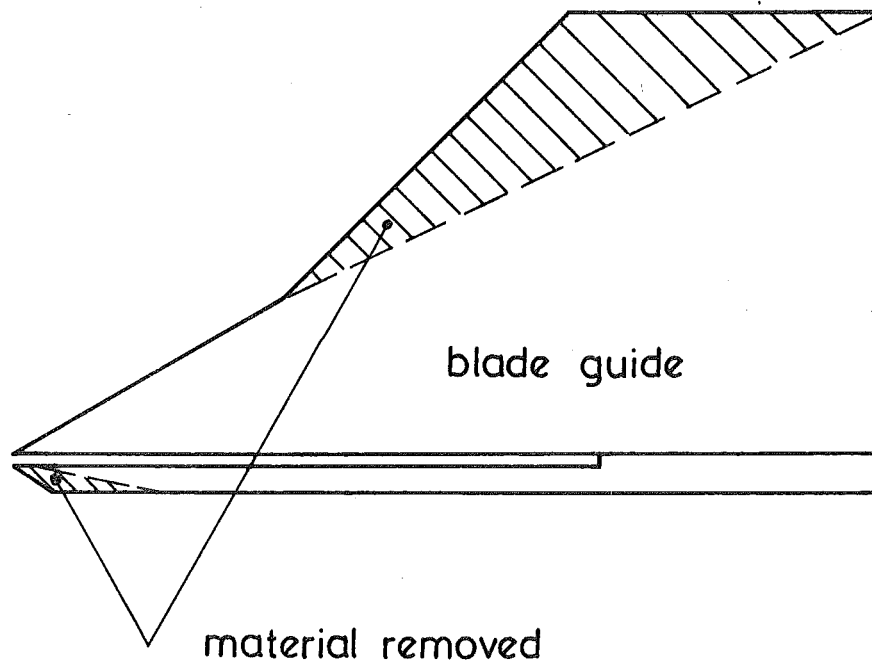


Fig 55 MACHINING OF THE BLADE GUIDE

The thrust bearings were observed to perform adequately, although grooving of the bearing surfaces was soon evident. It was considered that the tracking of the blade was not sufficiently positive to prevent rearward movement of the blade under load. However, for the purpose of evaluating the machine performance as a whole, the bandknife machine was satisfactory and the thrust bearings were easily replaceable.

Test runs showed that the only modification which affected the cutting and handling of individual skins, i.e. the machining of the guide, had a very large effect.

Skin damage was reduced and reliable cutting to one half inch was easily achieved.

A series of different settings of blade clearance, and blade angle, were then tried and a number of observations were made :

- (a) In nearly all cases the length of residual stubble increased along the direction of feed.
- (b) A length of uncut wool was invariably left around the edges of the skin. This was considered to be caused by the air flow into the suction roller bending the fibres onto the roller, and was largely unavoidable. This was estimated to be two to five percent of the total fleece.
- (c) Cut wool was found in the clearance between the blade guide and the suction roller following cutting.
- (d) The skins often attached themselves to the suction

roller so firmly that the scraper (A in Figure 50) could not remove them and jamming occurred. It was found that the skins could be forced into the gap of less than $1/32$ " between the scraper and the roller.

- (e) Many holes in the suction roller became blocked with fat and grease from the skins.

It was thought that (a) and (c) might be connected. Originally it was intended that the cut wool be blown over the blade and deposited on the conveyor, compressing slightly as the conveyor moved at a lower speed than the suction roller. However, as too large an air flow disrupted the cut fleece, the wool was probably not leaving the conveyor. In that event, the wool being moved at a slower surface speed than the suction roller could pile up on the belt beneath the blade guide and prevent the blowing system from bending the fibres over the blade.

Without building a transparent ducting this could not be directly observed. However, large air flows were used when cutting short woolled skins. The cut wool was then blown out of the duct without any possibility of piling up.

However, the problem of stubble length increase still persisted, and wool still appeared beneath the blade guide. The fleece on a woolly skin was painted with different colours in different areas and then cut. It was found that the wool, which appeared in the blade clearance, came from the trailing edge of the skin, and it was apparent that the fibres, bent over by the suction roller, were being cut and then held by the roller until they passed the blade.

The increase in stubble length remained. Different angles of the blade with respect to the roller were tried. A similar effect to that noticed with unguided blades was observed. There seemed to be no point of neutral stubble variation. Either there was an increase in the length or damage to the skin occurred. Although the mechanism was not clear, it was considered that unless the knife was extremely sharp, the edge of the blade moved up or down the fibre bunches, progressively increasing or decreasing the length of stubble. It was demonstrated that a very sharp edge produced by lengthy grinding reduced the stubble length variation.

Further tests were done with the relative speeds of the roller and conveyor altered and the feed-in rate reduced.

It was clear that a reduced feed-in rate produced a more even cut, and as the blade speed had been limited to its present value by sharpening requirements, an upper limit for the feed-in speed of approximately forty feet per minute was established. This would give a throughput of about 450 skins per hour. It should be noted that some stubble length variation was observed at all feed speeds.

When the suction roller surface speed exceeded that of the conveyor by more than about ten percent, longitudinal wrinkles appeared in the skin, causing damage to the skin during cutting. On the other hand, lateral wrinkles appeared when the conveyor moved at a faster speed than the roller. The correct adjustment of the ratio to 1.05:1 was necessary to ensure a smooth surface.

The sticking of the cut skins to the suction roller was

causing concern because of the possibility of the piling up action at the scraper being transmitted back to the cutting area. Obviously if the clearance between the skin removal roller (H) in Figure 51, was small enough that the skin was gripped firmly, this effect would be lessened. However, in order to remove any doubts about this effect, and to eliminate the chance of confusing scraper inflicted damage with blade damage, a skin removal system was built.

IX.4.7 Skin Removal System.

There were three possible solutions to the problem of detaching the skins from the roller :

- (a) An air jet system to lift the leading edge.
- (b) The blowing of air from inside the roller
after the surface had passed the suction area.
- (c) A counter-rotating scraper roller.

An air jet system, comprised of a row of nozzles directed at the leading edge of the skin proved unsatisfactory because insufficient force could be exerted with a standard 100 psi line.

The modifications needed to provide an internal blowing system were numerous and time-consuming. However, it was realised that the clearing of blockages in the roller surface could also be achieved by this system, and the use of air removal was considered a possibility for future machines.

Because the counter-rotating roller could be easily constructed, the decision was made to construct this.

A six-bladed flapper roller ((A) in Figure 56) was constructed. The six rubber blades brushed the surface of

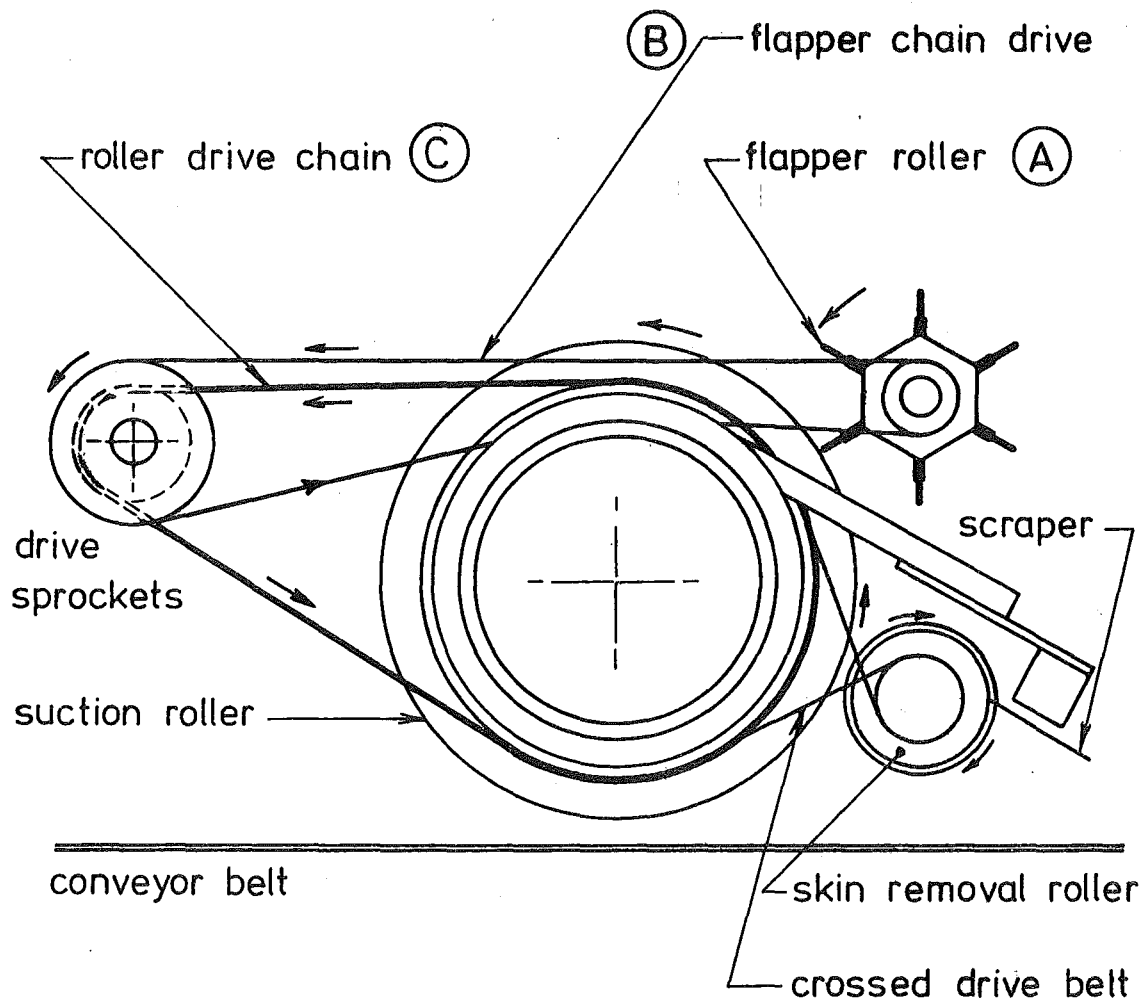


Fig 56 FLAPPER ROLLER AND DRIVE SYSTEMS

the roller and the tip speed was twice that of the suction roller surface. A chain (B) drove the flapper from the suction roller drive shaft.

Tests completed with this roller in place showed that skin removal was easily achieved although the installation of the flapper roller did not improve the cutting efficiency of the machine.

IX.5 DISCUSSION OF THE TESTS AND PERFORMANCE

It was clear that there were a number of problems yet to be overcome:

- (a) It had been demonstrated that the stubble length variation was not necessarily related to the piling up of wool in the ducting.
- (b) Because it was desired to keep the cut fleece intact, the air flow through the ducting was reduced. This lessened the bending effect on the fibres and it became doubtful whether sufficient flow to assist cutting was supplied.
- (c) Irregularities in the suction roller contour were more important than previously. Some distortion had occurred at the weld and the measured variation of radius was up to $\frac{3}{16}$ ". This was significant when attempting to cut to $\frac{1}{4}$ " stubble length.
- (d) Blockage of some of the roller surface holes was observed. The diameter of the holes (No. 52) was thought to be too small for continuous operation even if a cleaning device was installed. Both fatty matter and wool particles were found in the holes.

It was clear that major modifications were needed to overcome these difficulties. A proposed design, shown diagrammatically in Figure 57 was considered.

A suction roller (A) with larger (about 3/16" dia.) holes and an open area of around 0.4 would be mounted above two conveyor belts (B) and (C). The feed-in belt (B) would move at a speed V say, the roller at $1.05V$ and the take-off belt (C) at $1.1V$. This would prevent wool pile up under the blade (D). The increased speed of the belt (C) would be necessary to keep the area around the blade clear, because there would be a suction system (E) replacing the earlier blower and duct. With a suction system instead of blowing, greater flow rates across the blade were expected to be used without disrupting the fleece, as the wool would be forced down onto the conveyor rather than blown along it.

Air would be blown out of the roller once the skin had passed the suction area, and this would clean the roller as well as removing the skin as it passed onto a take-off conveyor (F).

This machine has not been built to date. It was decided to terminate this thesis with the end of development of the Mark 2 machine, as the financial support from the freezing companies had ceased.

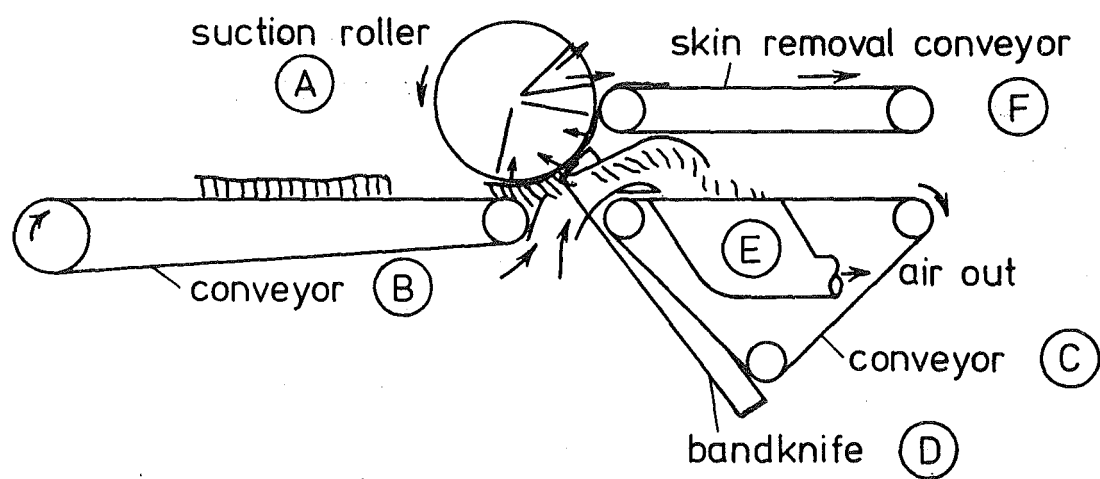


Fig 57 PROPOSED SKIN SHEARING MACHINE

CHAPTER X

SINGLE FIBRE CUTTING EXPERIMENTS

X.1 INTRODUCTION

It was considered that a knowledge of the basic mechanics of fibre cutting would be an aid to the design of blade profiles and selection of cutting speeds.

Although this was also approached on a macro scale in the disc cutting experiments described in Chapter II, a series of experiments on a micro scale were also carried out.

The severing of a single fibre in a shearing machine takes a very short period of time. A typical cross-bred sheep grows about 40×10^6 fibres over its skin. Assuming a uniform density, the linear cutting rate is approximately 10^3 fibres per second.

Also the fibres are very small. The diameters vary from 25 to 50 microns (1 to 2 thousandths of an inch).

In order to investigate or observe behaviour of the fibres of that size, during an operation of 10^{-3} seconds duration, special techniques were needed.

It was decided that the process would be observed because measurement of the small forces, deflections, etc. on such a scale was difficult.

X.2 SUMMARY OF FIBRE PROPERTIES

The wool fibre has a complex structure. Figure 58 is an illustration of the construction of the fibre. The central region (A) is often hollow or may be filled with

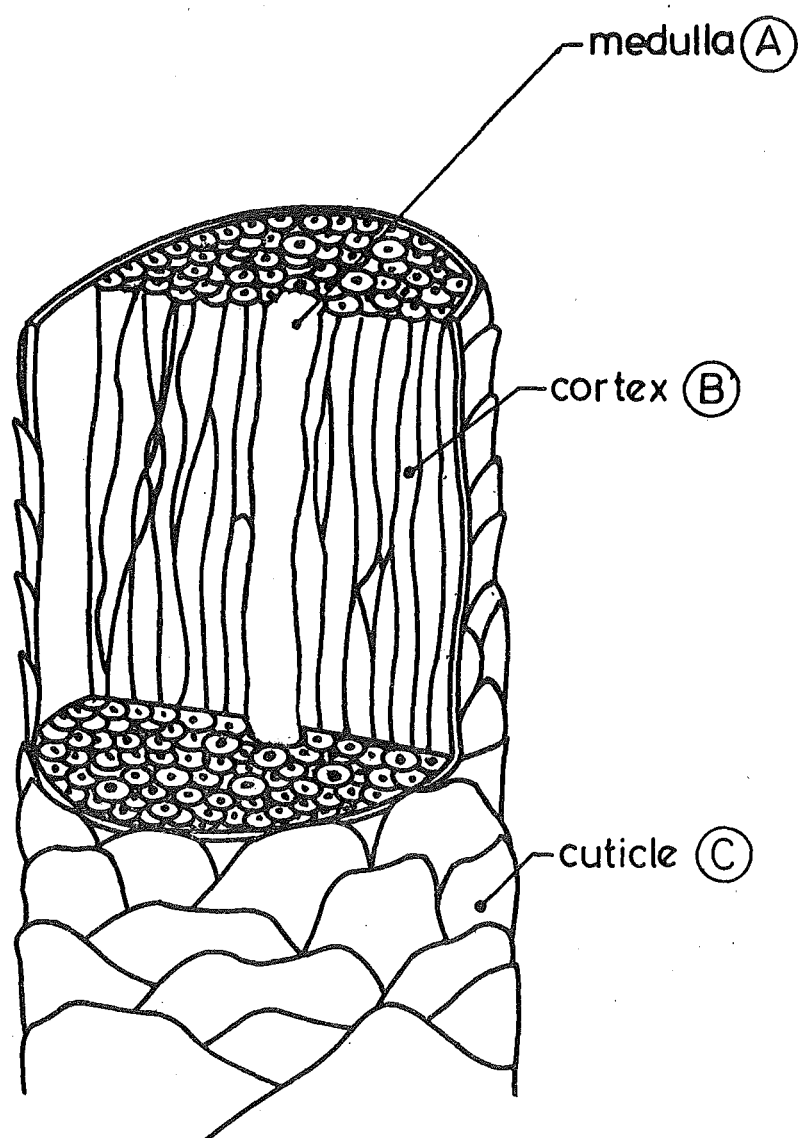


Fig 58 STRUCTURE OF THE WOOL FIBRE

a homogeneous, marrow-like substance called the medulla. Surrounding this are long cells of roughly circular cross-section called the cortex cells (B). These have a range of diameters from 5 to 10 microns and their length varies from 80 to 110 microns. The major axes of these cells are invariably parallel to the axis of the fibre. A layer of scale-like outer shells (C), of thickness 0.5 to 1 microns and depth 20 to 30 microns, are called the cuticle cells.

On unshorn sheep the fibres taper to a point at the ends but on shearlings the diameter of the fibre is uniform throughout the length. Wool is related to hair and horn and, apart from a short length in the skin, the fibres are dead matter.

Although the tensile strength of the fibres, and some other mechanical properties, are known, the properties of the component cells remain largely uninvestigated.

In general, it is recognised that the cuticle cells are harder than the interior regions but are relatively easily detached.

On the other hand, the chemical properties of the fibre as a whole, and the constituent parts, have been more thoroughly investigated.

X.3 INITIAL INVESTIGATIONS

It was decided that an optical magnification system would be used to view the cutting of single fibres. It was not known if the high cutting rates of the shearing machines was necessary, as the mechanism of the process may not have been a function of speed.

It was considered that the appearance of the cut ends of the fibres would give an indication of the similarity, or otherwise, of the mechanisms.

Examination of the cut ends of the fibres from band-knife machines revealed that dislodging of the cuticle cells, and some fraying of the severed cortex cells, was common around the cutting area. Cut fibres from other processes, e.g. hand shearing and knife cutting, showed slightly different amounts of damage.

It was decided that a small disc would be used to cut single fibres while the process was being observed by an optical microscope, and that the fibres cut by this slowly rotating disc would be compared with those cut by bandknife machines.

X.4 DESIGN OF SINGLE FIBRE CUTTING MACHINES

The requirement that the operation be observed through a microscope imposed several design limitations:

- a) As the working distance of an objective lens (i.e. the distance from the lens to the object) is only a few millimeters and decreases as the magnification increases, the lens must be positioned close to the fibre.
- b) The depth of field of an objective lens (i.e. the vertical range over which the object remains in focus) is generally a few microns, again decreasing as magnification increases.

As a result of the small depth of field, it was necessary that either the lens follow any movement of the fibre or the fibre be held in the same place during cutting.

The latter suggestion was the more easily achieved, but the fibre would then have to be held more securely than would be the case in a bandknife machine.

Because of the short working distance, a cutting disc of small diameter was needed if the operation was to be observed from above the fibre looking down on the vertical cutting edge. This line of view was considered to offer the best possibilities for observing the cutting action.

Because the process was to be observed at as high a magnification as possible, the cutting area was required to be well illuminated. It was expected that a combination of reflected and transmitted light techniques would be used.

X.5 DESCRIPTION OF THE MARK I MICROCUTTER

The first single fibre cutting machine which became known as the microcutter and will be referred to as such, is shown in Figure 59 and Plate 12. The cutting element was a 10 mm diameter steel disc with a double bevel ground edge. This was pressed onto a shaft (B) rotating in plain bearings in an aluminium block (C). The shaft was turned by hand, by means of a thumbscrew (D). The aluminium block was able to move along a slideway and was controlled by another thumbscrew (E). The wool fibre was held by clamps (F) across a slot in a fixed block (G) at the end of the slideway.

As the aluminium block carrying the disc was slowly advanced and the disc edge contacted the fibre, the disc was turned by hand and the process observed by a microscope from above. Light was transmitted to the objective from a light source mounted below a hole in the slideway, directly

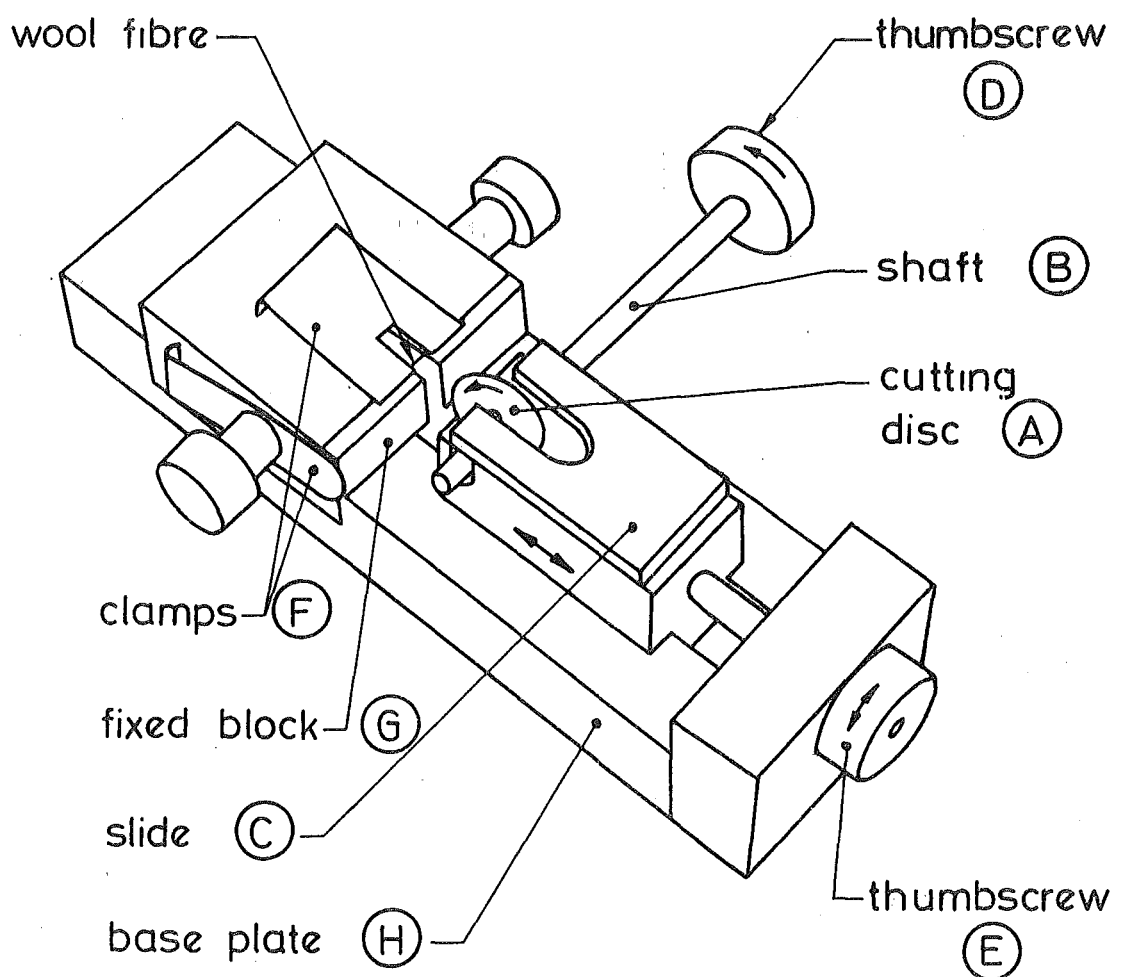


Fig 59 MARK I MICROCUTTER

beneath the fibre.

An Olympus camera was mounted on the microscope and exposures were taken at - for example - each complete turn of the disc.

X.6 OBSERVATIONS USING THE MARK I MICROCUTTER

During the first part of the cutting operation, cuticle cells were seen to be dislodged, either in whole or in part.

The errors in machining the disc showed as large movements at magnifications of 100 times and over, and the edge could be seen to move up and down the fibre as the disc turned.

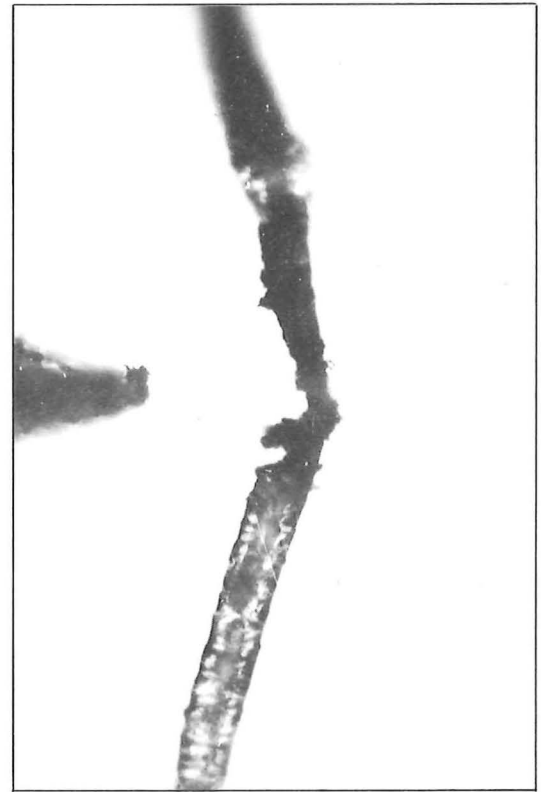
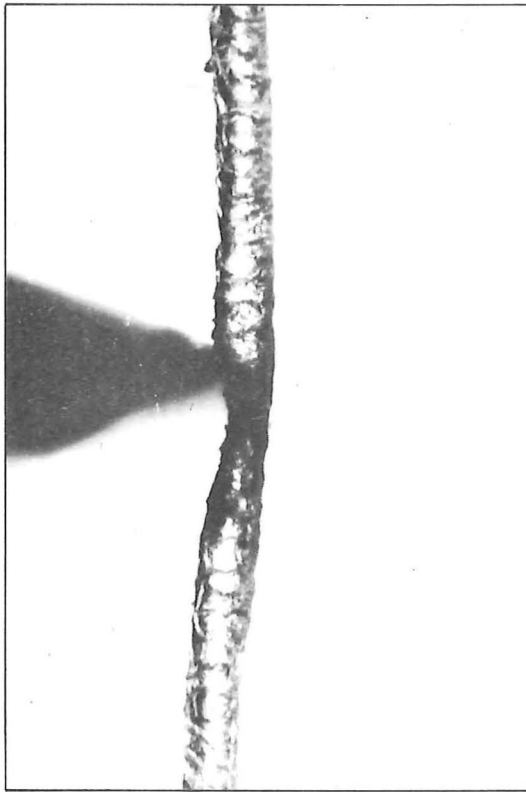
This movement apparently resulted in a wearing of the cortex cells following dislodgement of the cuticle scales.

Finally, failure occurred through parting of the remaining cortex cells in a manner that suggested tensile failure.

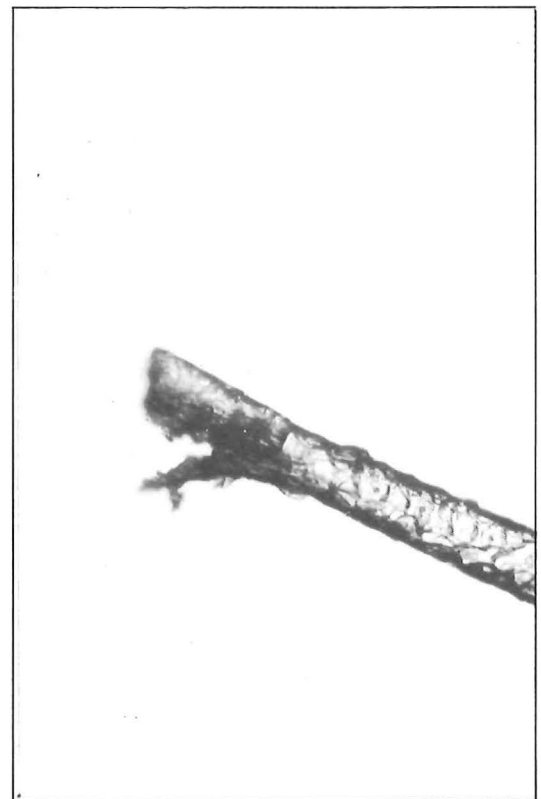
Plate 13 illustrates the appearance of fibres during and after, cutting.

The maximum deflection before failure for an initially taut but unstretched fibre was of the order of one to two millimetres. The free length was 1.5 millimetres .

It was found that the radius of the edge of the disc was of a similar magnitude to the fibre diameter, even after fine lapping of the disc had been carried out. Consequently, wearing, rather than shearing, was likely to be the basic mechanism.



fibres during cutting



examples of the cut ends

The validity check of the damage done to the ends was then carried out to determine how typical the process really was.

X.7 VALIDITY CHECK

The method of assessing the fibre damage was as follows: Slides, with cut fibres mounted beneath a cover glass, were observed through a microscope. The objective lens of this microscope had a graticule fitted to it and this was able to be moved so as to align the graduations with fixed objects such as the fibres. In practice the marks were aligned normally to the fibre under observation, and the distance from the last undamaged part of the fibre to the tip of the fibre was measured (refer to Figure 60)

There was a large variation in the amount of damage done, but the mean damaged length to diameter ratio for microcut fibres was 0.72, and the corresponding figure, for bandknife cut fibres, was 0.47.

It should be noted that the standard deviation of both microcut (.31) and bandknife cut (.27) was large. Consequently, there were a large number of fibres that could have been cut in either manner. However, there was no way of predicting that, in any given run, more or less damage would result and the variance in the means was taken to indicate that the cutting processes did differ.

Attention was then given to the design of a micro-cutter which cut at feed-in rates comparable to bandknife machines and with an edge speed comparable to bandknife machines.

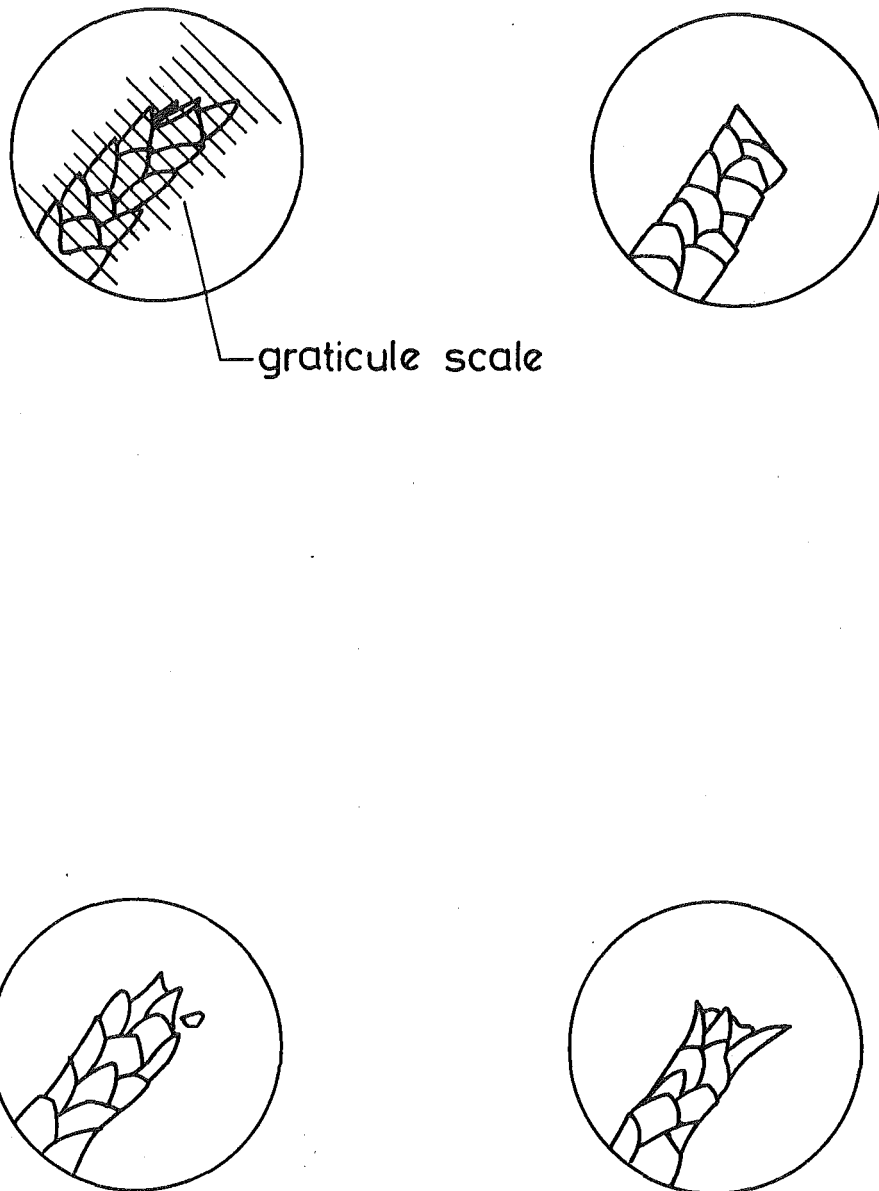


Fig 60 APPEARANCE OF MICRO CUT FIBRES

X.8 THE MARK II MICROCUTTER

The principle of cutting with a disc, and viewing the fibre from above, was retained.

As a power source for the ten millimetre diameter disc, a dentist's air turbine was obtained. The disc was then mounted on the shaft where the dentist's drill is normally fixed. The requirement that the disc be powered, and hence be mounted on the turbine, which had air lines and oilers attached, led to the adoption of a system of feeding the fibre into the disc.

The Mark II microcutter is shown diagrammatically in Figure 61 and in Plate 14.

The base of the machine (A) had a vee way (B) screwed onto it. The sliding block (C) had the fibre mounted across a 2 millimetre slot. Clamps (D) gripped each end of the fibre. The block was driven up and down the slide by a screw which, in turn, was driven by a small electric motor (E). Microswitches stopped the slide at the extremities of movement and speed variation was simply achieved by alteration of the power supply voltage.

At the end of the vee-way there was a support pillar holding the turbine (F) and the cutting disc (G). Air was supplied to the turbine from a 100 p.s.i. line via a throttling valve to achieve speed regulation. A lubricator was incorporated in the system as the turbine bearings were very delicate.

Light was transmitted from beneath the machine through a hole in the bedplate and, when the block had moved forward, through the slot over which the fibre was held. Because

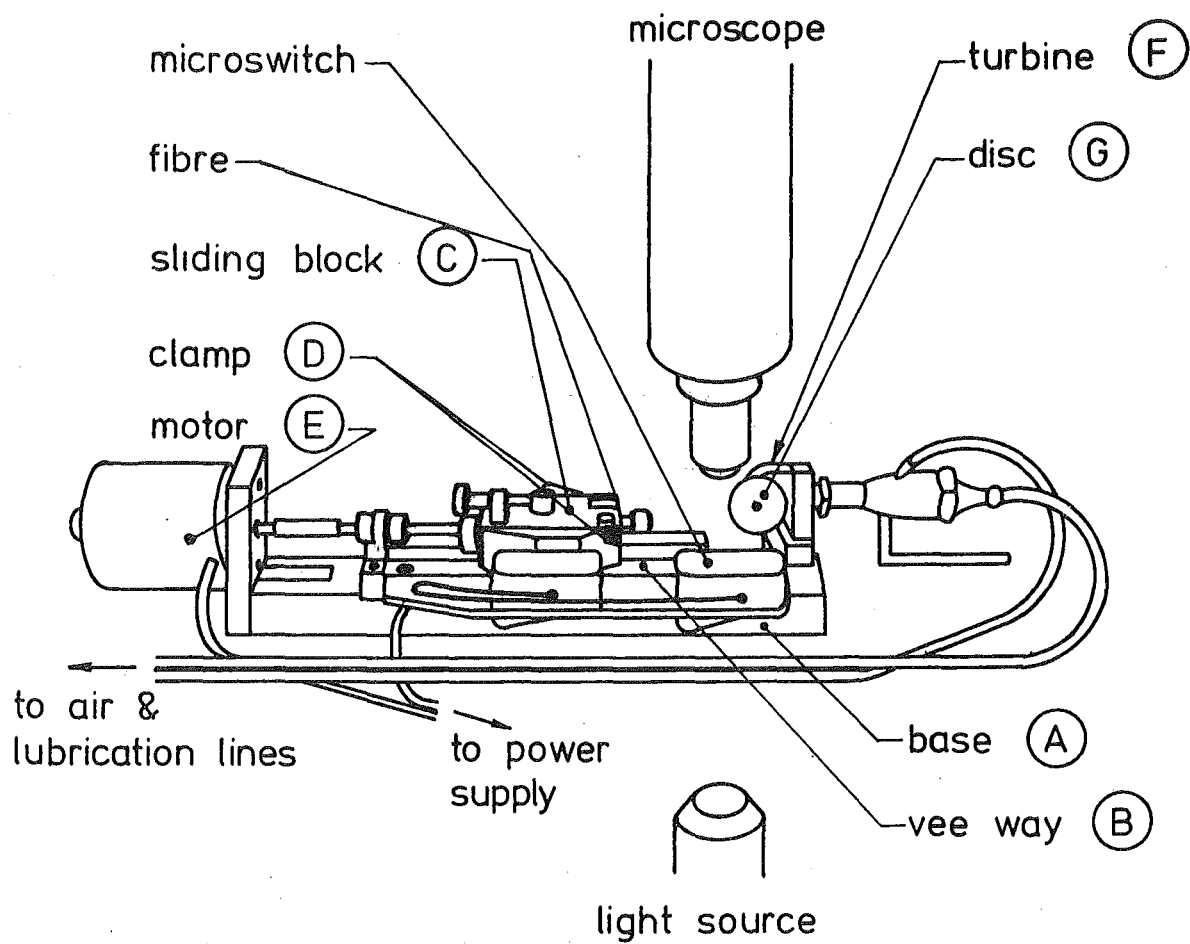


Fig 61 MARK II SINGLE FIBRE MICROCUTTER

the block moved to feed the fibre to the disc, focussing had to be done prior to the run by moving the block until the fibre appeared in the field of view, and then moving the block back to the starting position.

As the human eye is incapable of recording events of the duration of 10^{-3} seconds, other recording systems were necessary.

X.9 TESTS WITH THE MARK II MICROCUTTER

X C.9.1 Multiple Image Photography As the fibres were held in clamps and a constant tension could be arranged, it was expected that the deflection before failure could be an indication of the relative effectiveness of different blade angles and cutting speeds.

In order to measure this deflection and to observe the appearance of the fibre during cutting, a multiple image exposure was made.

A stroboscope ((A) in Figure 62) which had a variable time base, was used as the light source. As cutting began the shutter of a camera (B) mounted on the microscope was opened and a number of images of the fibre in deflected positions were recorded. Examples of these types of image are shown in Plate 15.

It was found that the illumination, using the stroboscope, was insufficient to enable magnifications large enough to observe the cutting process to be used. The maximum deflections observed had a large range with standard deviations of similar magnitude to the mean, and this was

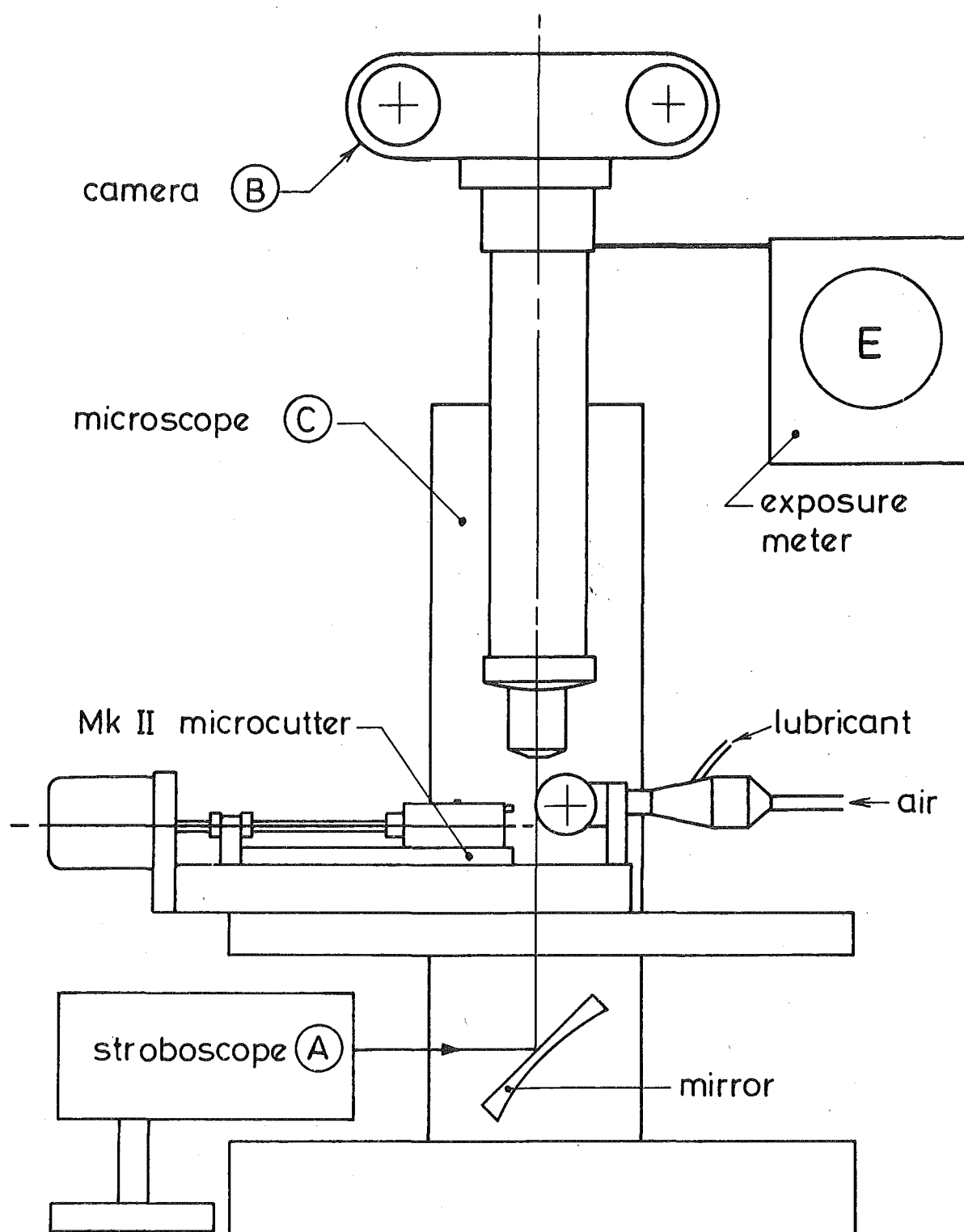


Fig 62 MULTIPLE IMAGE PHOTOGRAPHY APPARATUS

considered an unreliable guide to performance.

It was calculated from the flash duration and number of images, that the fibre was cut in about 10^{-2} seconds - not the expected 10^{-3} seconds. It was apparent that the support given to fibres by the surrounding fleece and the wool root was of similar effect to gripping the fibre at each end, and that the throughput of 10^3 fibres per second was too great for the disc edge speed.

It was also likely that a tensile failure occurred in the fibre because of the high feed-in rate

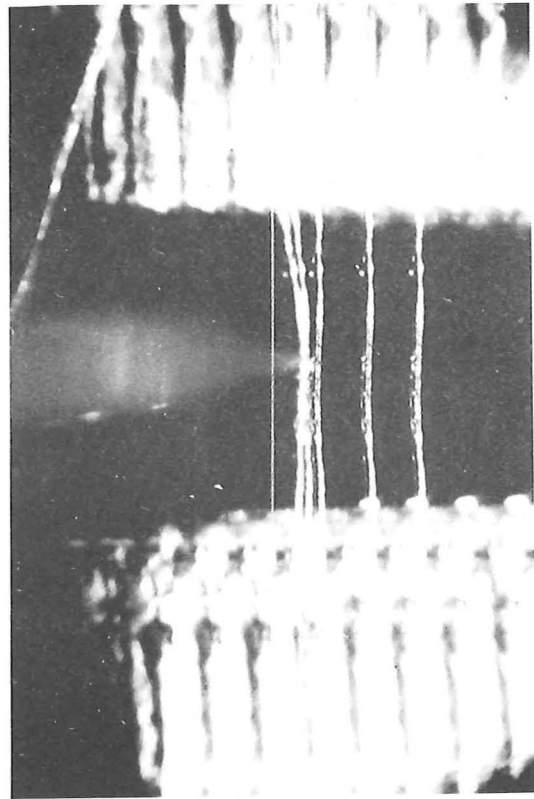
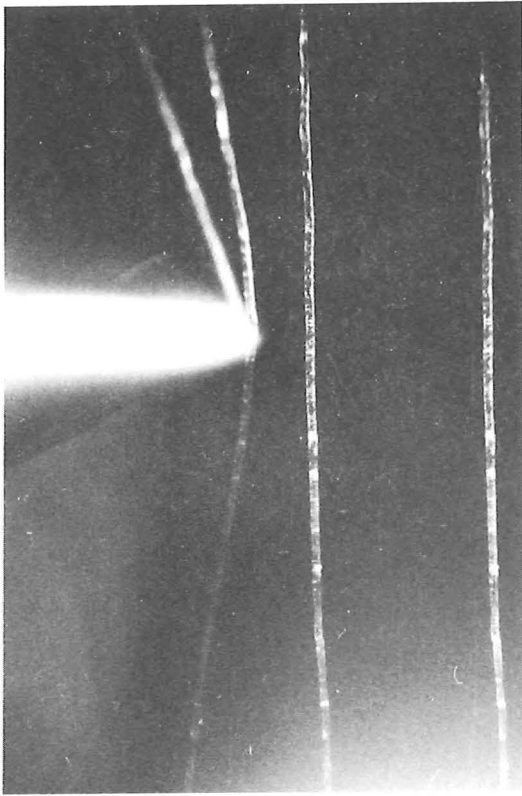
X.9.2 High Speed Photography It was decided that a high speed camera (having a speed of the order of 10^3 frames/second) would be used to record the event.

At the time that this was being done, development work on the bandknife machine had indicated that the reduction of both feed-in speeds and blade speeds was necessary.

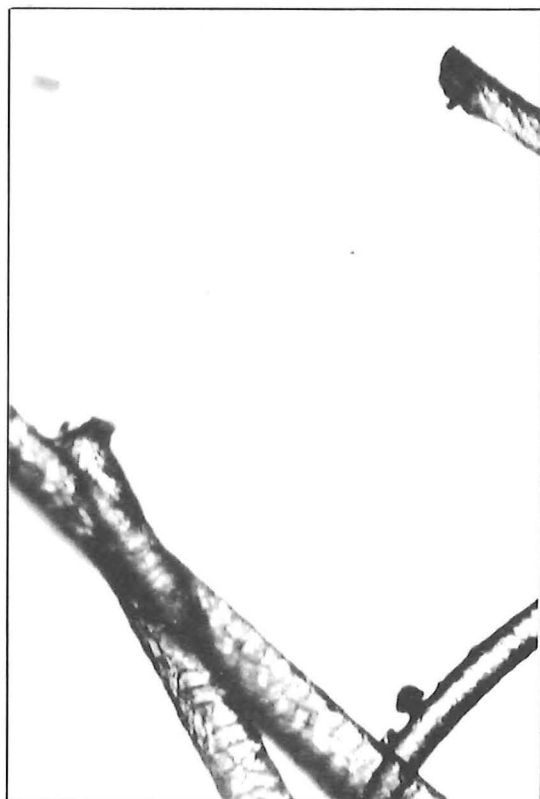
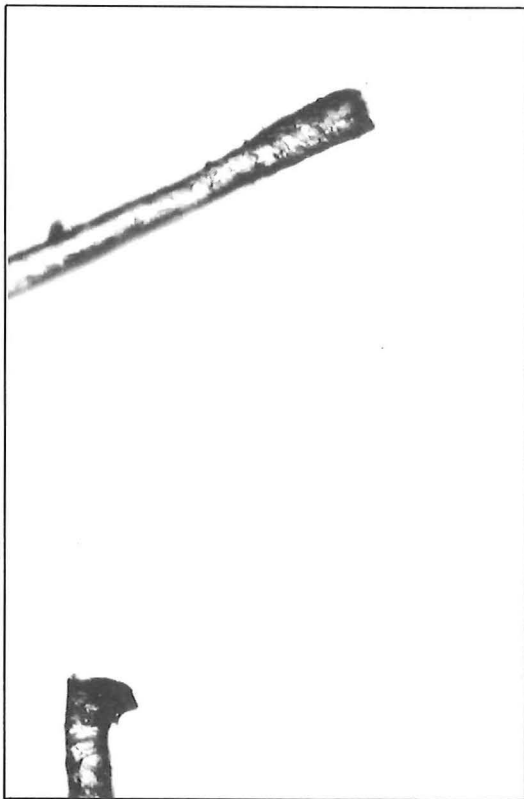
Consequently, with a feed-in speed of nine inches per second, the fibre cutting rate was reduced to about 7×10^2 fibres per second. (1.4×10^{-3} seconds per fibre). A Beckman and Whitely camera was available and this had a maximum speed of 3.2×10^3 frames per second (3.1×10^{-4} seconds per frame). As a result of this, a typical cut was expected to cover approximately five frames.

The blade speed was capable of being varied to a maximum of 250 feet per second (150,000 r.p.m.) and was set for these tests at 100 feet per second (60,000 r.p.m.)

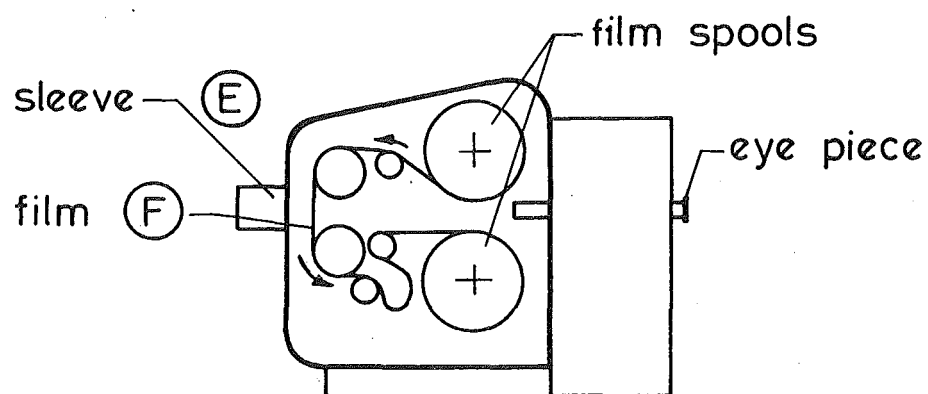
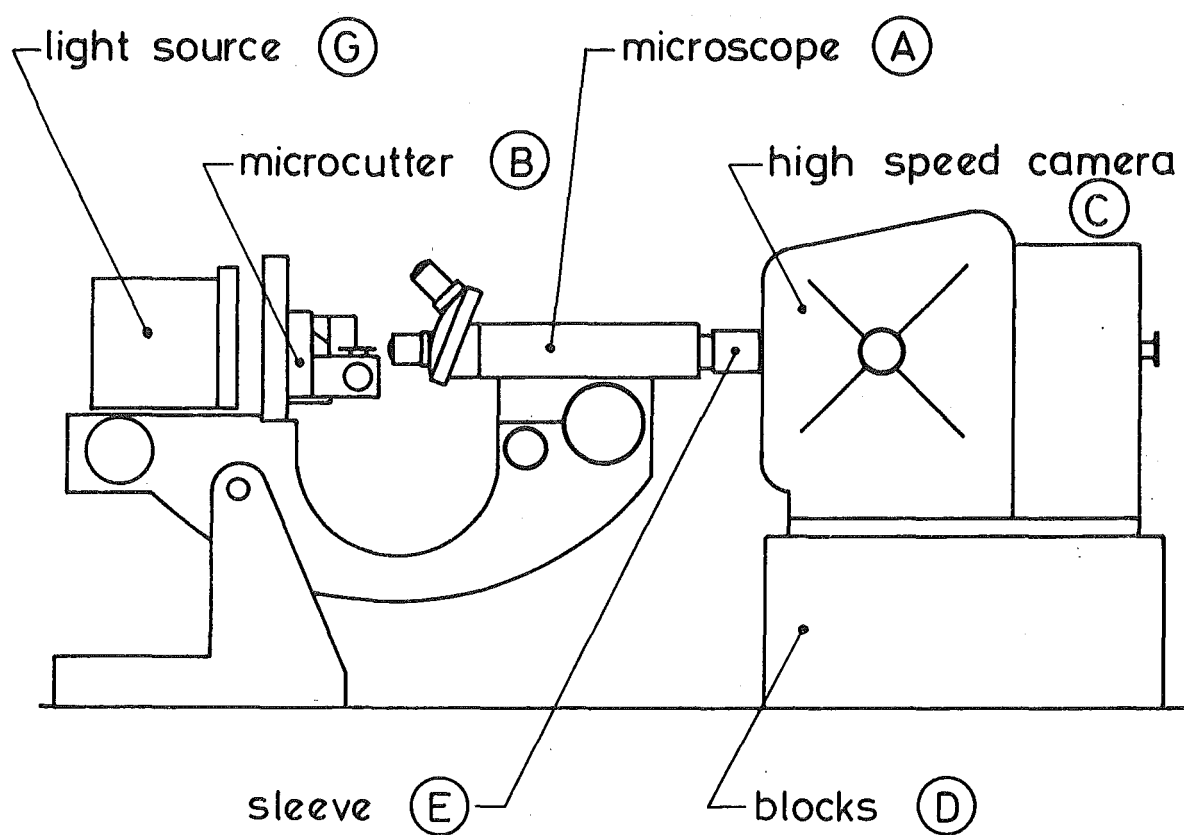
The experimental apparatus is shown diagrammatically in Figure 63. The microscope (A) carrying the microcutter (B)



typical sequences
($\times 50$)



examples of cut ends ($\times 300$)



Camera with cover removed

Fig 63 HIGH SPEED PHOTOGRAPHY APPARATUS

was rotated in its frame until the lens tube was horizontal. The high speed camera (C) was mounted on planed blocks (D) and the lens of the camera was replaced by the sleeve (E) which surrounded (but did not touch) the eyepiece of the microscope. This reduced the vibration transmitted to the microscope from the camera mechanisms.

With the camera lens removed, the image was focussed directly onto the film in the camera (F).

The camera possessed a timing device. This device tripped a switch, either opening or closing a circuit, after any number of feet of film had passed through the camera. It was observed that the slide on the microcutter took an average of two seconds to accelerate to speed and reach the fibre. The film in the camera reached maximum speed after about 60 feet had passed through the spools. This took approximately $2\frac{1}{2}$ seconds. Consequently, the timing device was set to turn the slide drive on after 10 feet of film had been run.

Illumination of the fibre was achieved by focussing light from a fifteen watt microscope light source (G) through a condensing lens. (Hidden in the diagram).

In operation there was a formidable check list to go through before the final operation of starting the camera.

- a) The microcutter slide was moved so the fibre was in the field of view of the microscope, and focussing was done on a strip of frosted film in the camera.
- b) The slide was returned to its initial setting and the camera timing device set.

- c) A reel of film was loaded into the camera and the speed and spool stops were set.
- d) The slide power supply was set to a value of nine volts and the feed switched to forward.
- e) The power to the light source was slowly brought up to the maximum (fifteen volts for the microscope lamp)
- f) The air turbine was started and set to the desired speed using a stroboscope.
- g) The camera was started and the cutting then took place after the preselected length of film had been run.

X.9.3 Film and Processing The fastest available film suitable for the double tracked camera spools was Kodak Tri-X. This has a speed rating of 600 A.S.A., but, by developing in Acufine, this was increased to 3000 A.S.A.

In other respects the processing was identical to that of any movie film, but reversal was not considered necessary, particularly as prints were taken from the film.

X.10 RESULTS

Early runs indicated that there was insufficient illumination when using the microscope lamp. Consequently, a 200 watt halogen lamp from an Eiki projector was used in later runs.

Examples of the sequences obtained are shown in Plate 16. A number of runs were done with slight differences in the positions of the light source, and shadow guards, etc. before pictures of the quality shown were obtained.

Another validity check was carried out (refer X.7). The mean damage length for a number of fibres was .55 (.47 for bandknife cut fibres) with a standard deviation of .28 (.27). This indicated that the microcutter was producing a cutting action very similar to that of a full size band-knife.

The observed cutting action was calculated to take an average of 4×10^{-3} seconds. This was longer than expected but it should be noted that there was considerable variation from fibre to fibre.

A similar action to that observed in the earlier tests was observed. Dislodgement of the cuticle cells was followed by cutting or wearing of the cortex cells.

The irregularities in the disc could clearly be seen as from frame to frame the edge was observed to move:

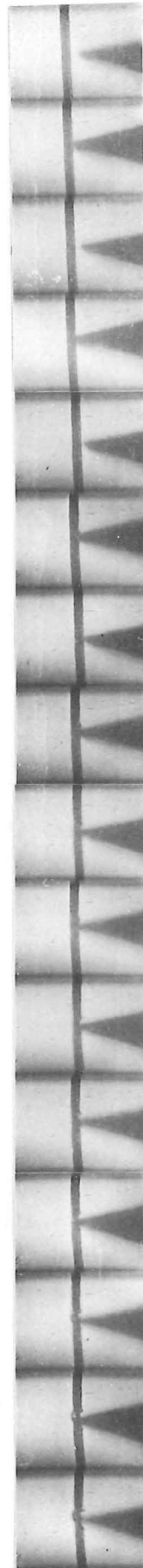
- a) Back and forth along the fibre, and
- b) Radially with respect to the disc axis.

It was noted that the time to cut the fibre was reduced by sharpening the disc prior to cutting. Even the cutting of single fibres had a significant effect on the sharpness of the disc. (This could be assessed visually after a number of fibres had been cut by microscopic examination of the edge).

One reason for the slightly greater damage to fibres cut by this method, compared to those cut on a bandknife, could be that the fibre is able to follow the blade on a bandknife machine because it is held less rigidly, avoiding the wearing action of the microcutter.



1



2



film speed=3000
frames/sec
film:Kodak
Tri-X
magnification $\times 100$

developer:Acufine
edge speed
100 feet/sec

Attempts to film the bandknife cutting process had been unsuccessful because of the presence of the cut wool.

Because the development of the technique of combining high speed photography with high magnification had been time-consuming, and for economic reasons, the further investigation of single fibre cutting, namely the variation of disc sharpening, speeds, etc., was regretfully suspended in favour of intensive development of the Mark II shearing machine.

X.10.1 Notes on the Sequences shown in Plate 16

- a) The black object seen to the left of the fibre in sequence 1, was a piece of plasticene. Plasticene was used to aid the holding of the fibre and, in this case, a small particle was left in the field of view.
- b) The irregularities of the cutting edge can be clearly seen, in both sequences, as a horizontal (radial) movement and a vertical (axial) movement from frame to frame. As the observed movements are about one fibre diameter, the blade was running with an eccentricity of approximately .001". This could be improved by using precision grinding machines to form the disc, but the blade in a working machine will not necessarily be accurately positioned. It was felt that the microcutter represented the real process as it was, and the validity checks (X.10) confirmed this.
- c) After being cut, the fibre halves may be seen to rub on the disc, as would the cut stubble on a bandknife machine.

CHAPTER XI

WOOL REMOVAL : THE FUTURE

It was considered that a modified machine, such as that described in Chapter IX, Section 5, could cut wool from the skins at least as close as 3/8" from the skin.

The increase in stubble length, which had proved difficult to avoid, could be affected by the nature of the blade edge. An investigation of the effects of different blade profiles, and different grinding wheel types, would be profitable.

In the long term operation of such a machine, the build-up of fatty matter, wool particles, etc. in some areas, would have to be overcome. Some effects have been investigated and overcome (refer to Chapter IX, Section 4.4, blade seizure), but others, such as blockage of the suction roller holes, remain to be resolved.

At the time of writing, minor modifications were being carried out on the machine as the need for these arose.

However, the future of mechanical wool removal has been challenged by a rapid action depilatory. This depilatory, which takes effect in an average of two hours, still has many of the disadvantages of the lime sulphide depilatory, particularly in its effect on the wool. Because the chemical is highly alkaline, the wool roots are easily removed, but damage to the useful part of the fibre is difficult to avoid.

However, the problem of pelts overheating in the stacks no longer exists, and the shorter time from painting

to pulling is an advantage. The Technical Committee of the New Zealand Freezing Companies decided to investigate this process, and not to continue supporting the mechanical removal project. In the absence of further financial assistance, major modifications are not possible.

The microcutting investigations have also reached a turning point. The technique of photographing the cutting process has been finally achieved, and at this stage, expert interpretation of the process is needed. Again, investigation of the effects of the edge profile of the cutting disc would be profitable, as would the use of higher magnification devices with greater depths of field, such as a scanning electron microscope.

APPENDICES

- APPENDIX I: Calibration Curves for Model Wool Cutting Machine. (Figures 64 and 65).
- APPENDIX II: Graphs from Sliding Tests of Skin Samples on Plates and Meshes. (Figures 66 to 72).
- APPENDIX III: Suction Roller Calculations.
- APPENDIX IV: List of Bandknife Manufacturers.
- APPENDIX V: Stress Calculations for Bandknife Machine Wheels.
- APPENDIX VI: The Reise Raw Skin Shearing Machine.
- APPENDIX VII: Alternative Methods of Wool Removal.
- APPENDIX VIII: Workshop Drawings.

NOTE: Only important stress calculations are included. In the interests of brevity, routine calculations of the strength of structural members, shafts and bearings are omitted.

In all cases stresses in these parts were not permitted to exceed the fatigue limit for the material they were comprised of.

APPENDIX I

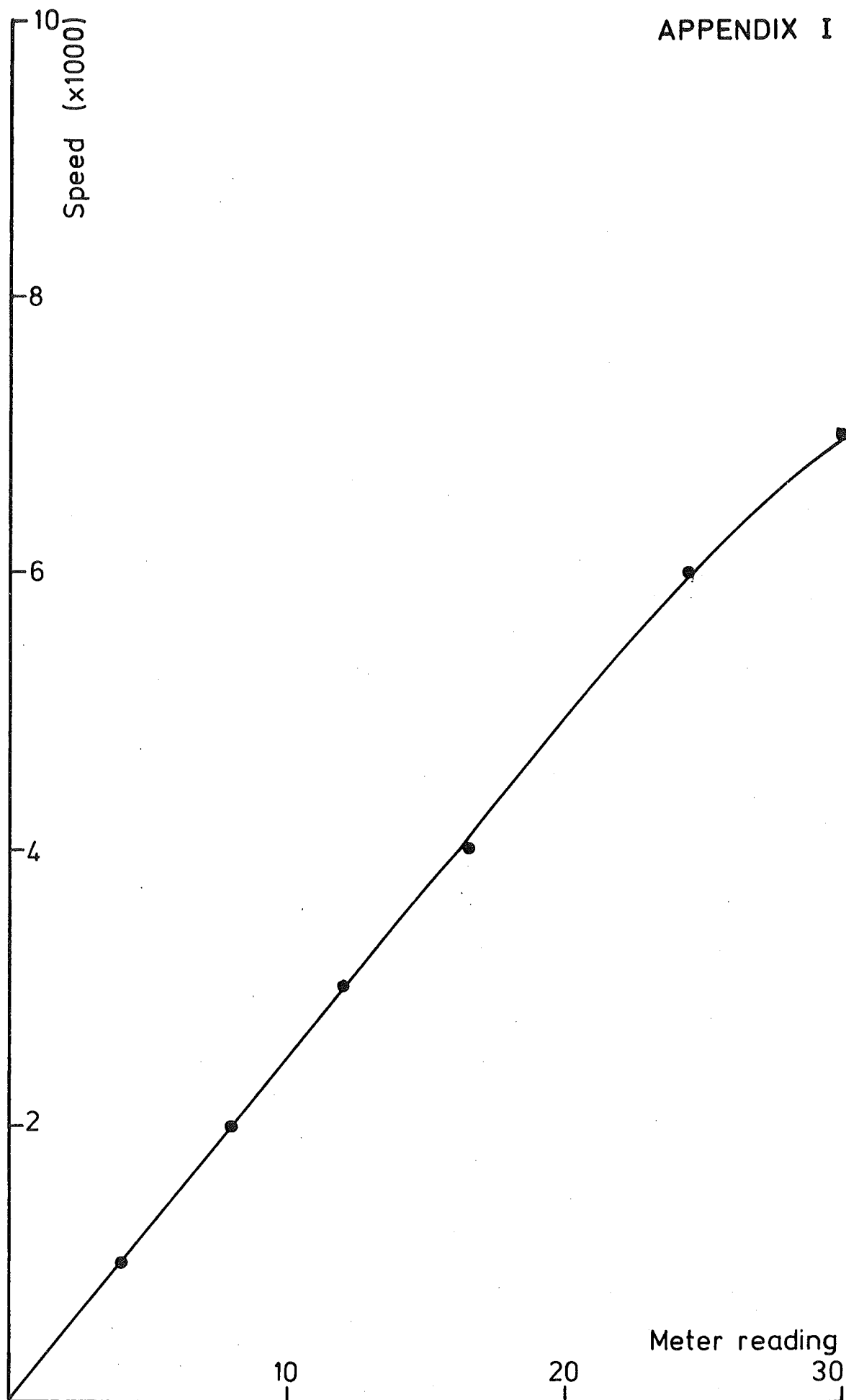


Fig 64 CALIBRATION CURVE: SPEED vs METER READING

APPENDIX 1

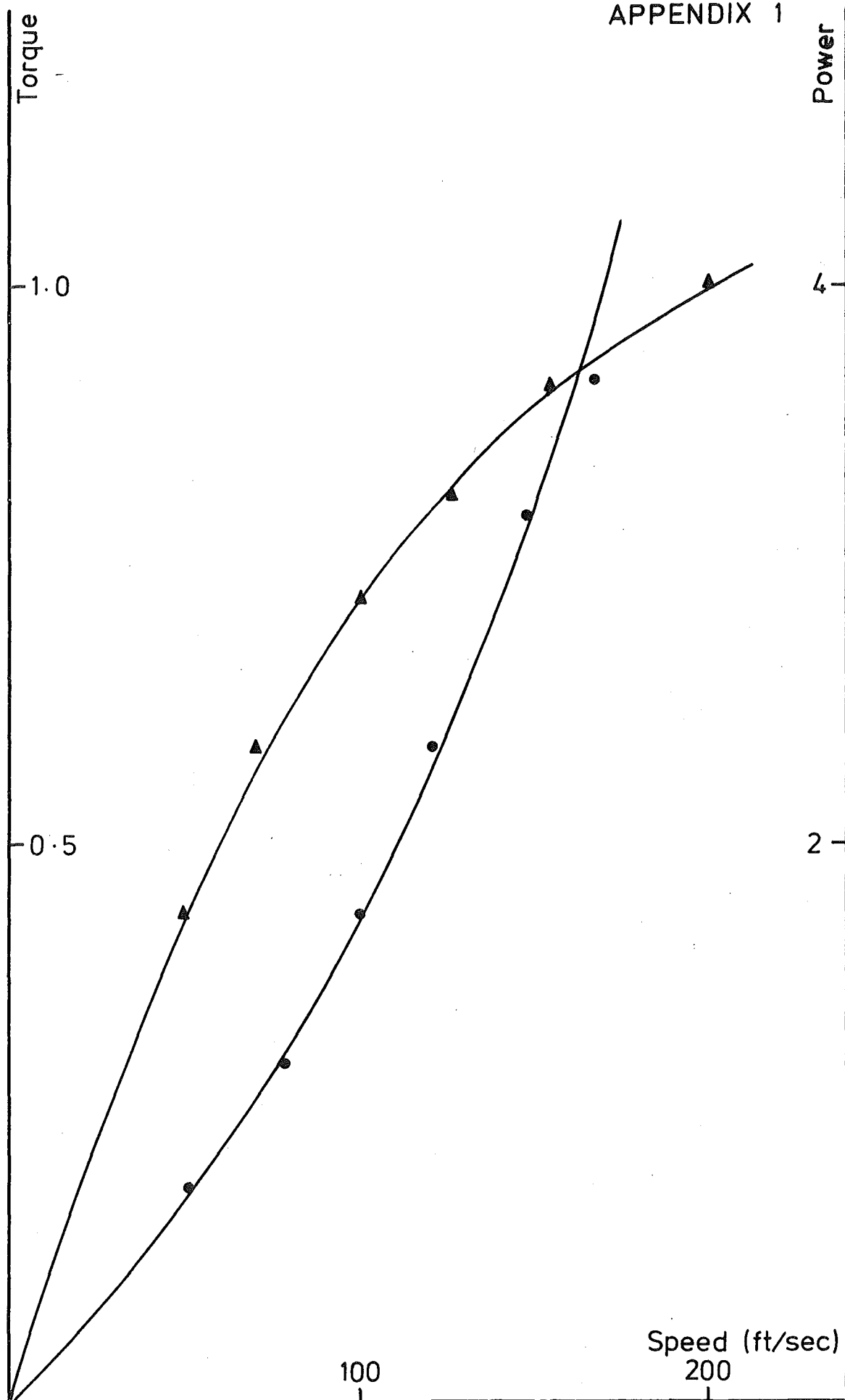


Fig 65 CALIBRATION CURVES POWER/TORQUE vs SPEED

APPENDIX II

The graphs on the following page are the results of experiments conducted with the O.B. and 3½ V.B. Fan, described in Chapter VII. Note: Pressure vs. Power Gradients have an arbitrary value.

PLATE	COVER	R ₁ PRESS/POWER	R ₂ FORCE/PRESS lb in H ₂ O	R ₁ x R ₂
56	None	1	.23	.23
56	B30,B60	1.08	.29	.31
56	S20	1.16	.29	.34
56	B80,S50,S80	1.2	.29	.35
52	None	.16	.46	.07
52	S20,B30	.27	.36	.09
52	B60	.53	.36	.2
52	S50,S80,S50	.8	.36	.29
30	None	.18	.64	.12
30	B30	.25	.82	.08
30	S20	.32	.32	.10
30	B60	.43	.32	.14
30	B80,S80	.48	.32	.15
30	S50	.5	.32	.16
24	None	.18	.51	.09
24	S30,B30	.32	.39	.13
24	B60	.48	.39	.19
24	B80,S80	.56	.39	.22
24	S50	.61	.39	.24

APPENDIX 2

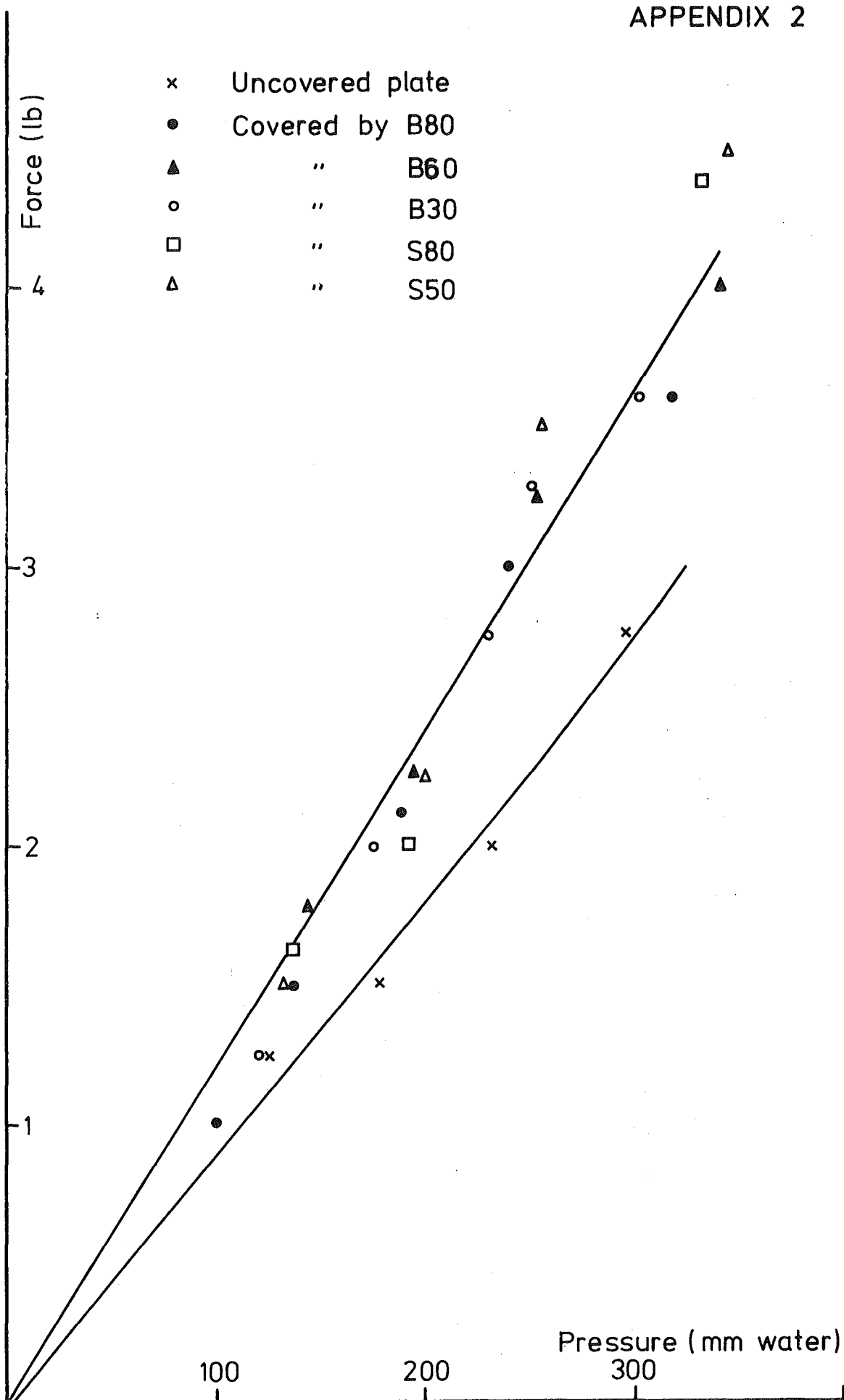


Fig 66 SLIDING FORCE vs PRESSURE. N° 56 PLATE

APPENDIX 2

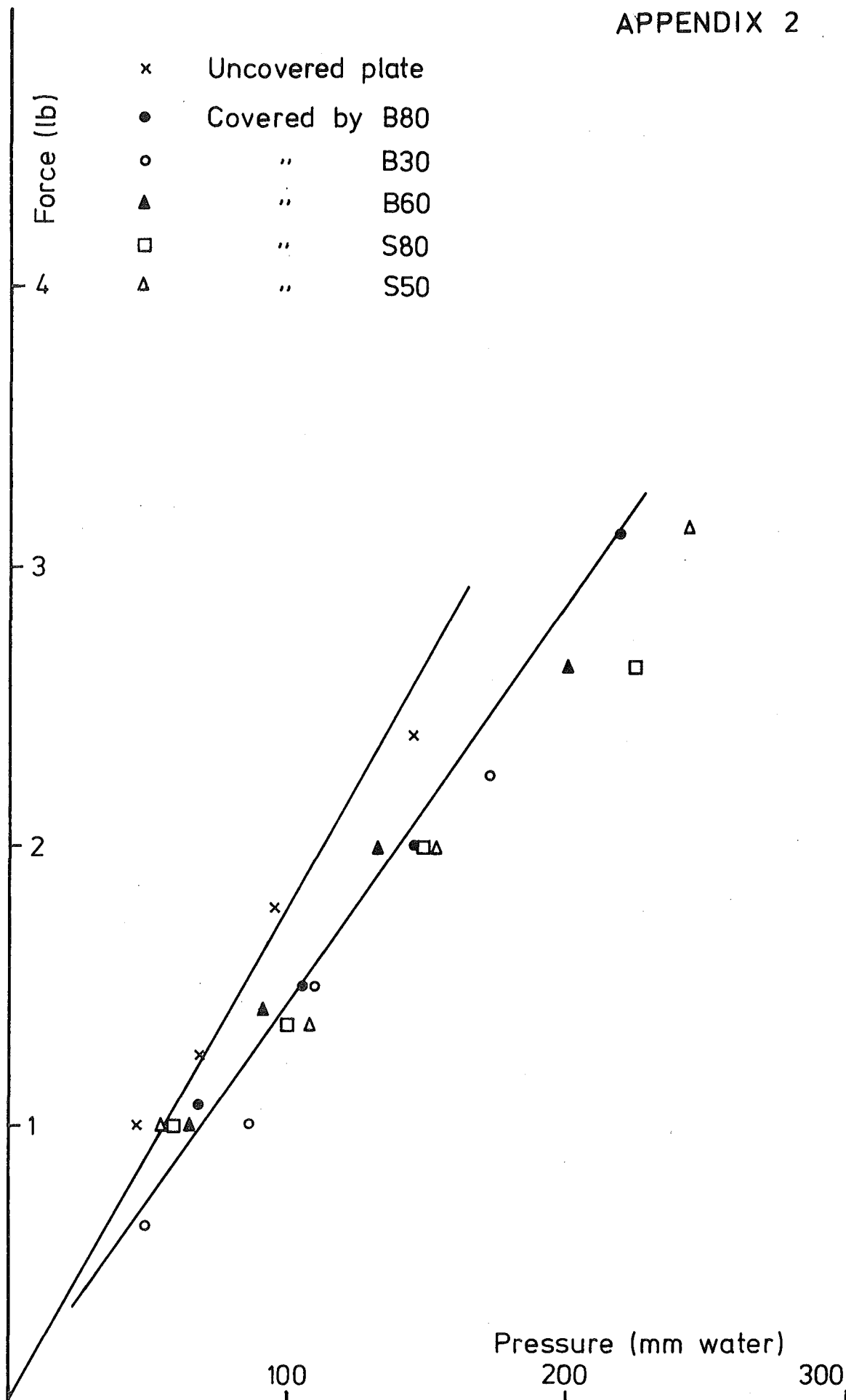


Fig 67 SLIDING FORCE vs PRESSURE N° 52 PLATE

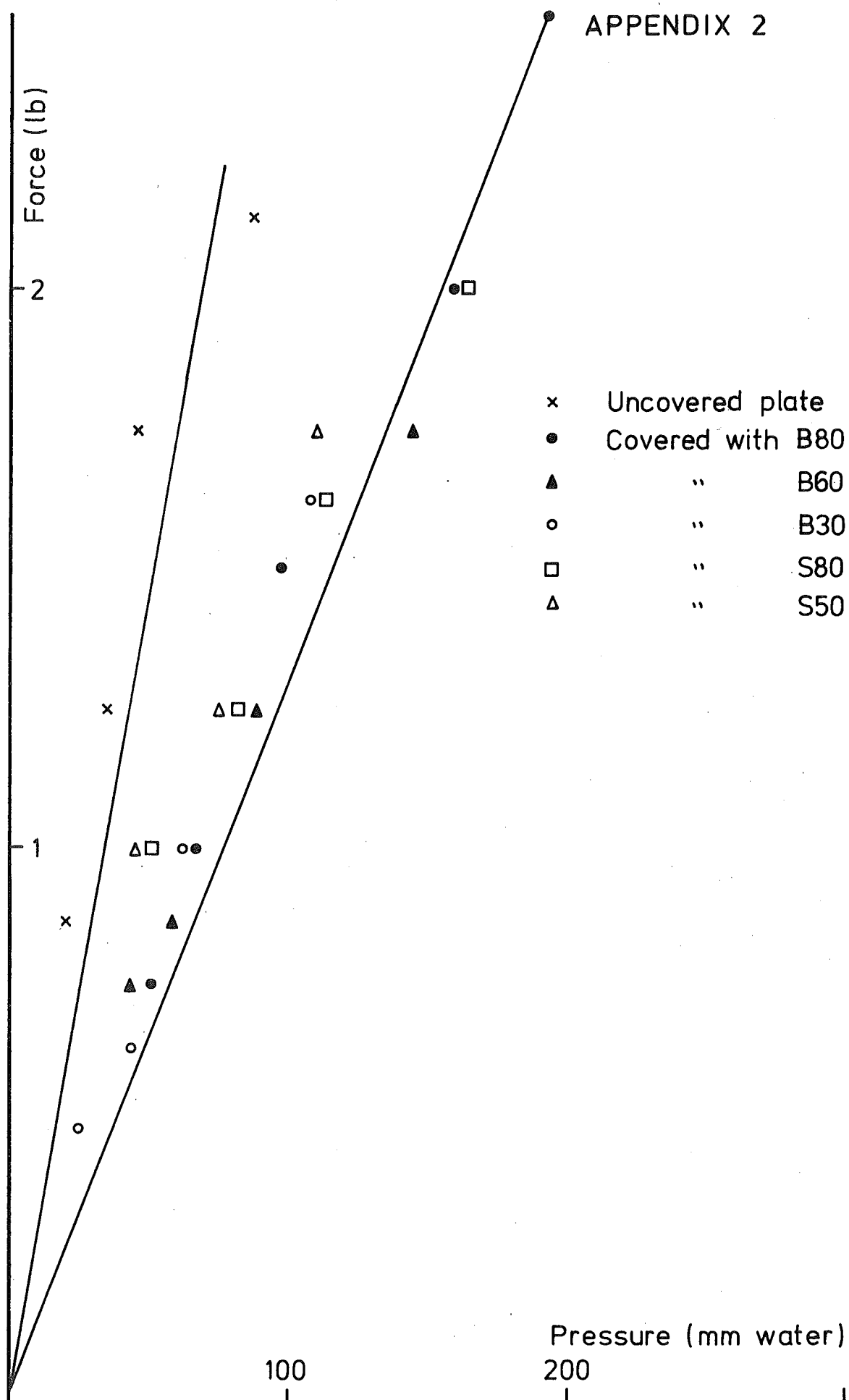


Fig 68 SLIDING FORCE vs PRESSURE N° 30 PLATE

APPENDIX 2

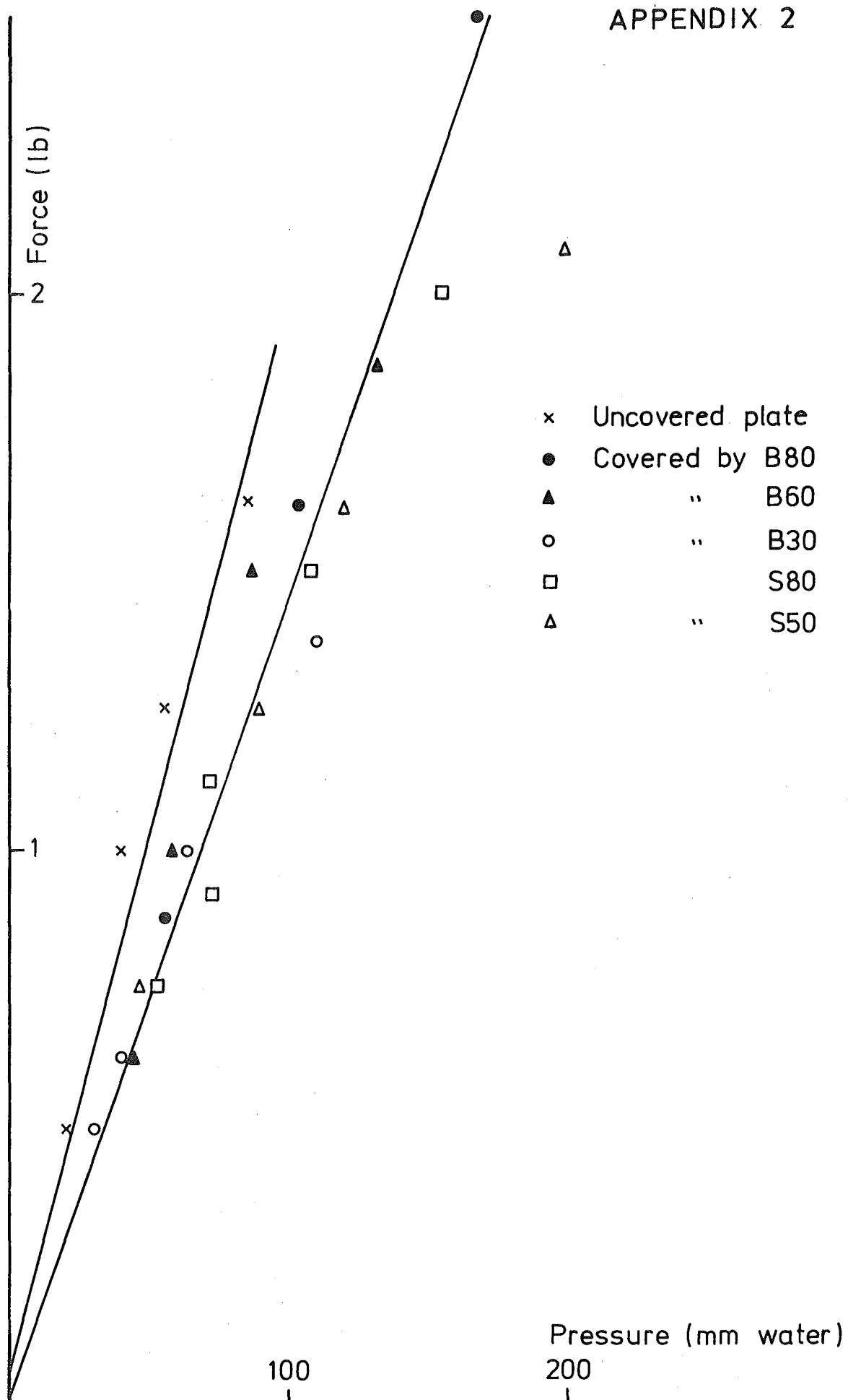
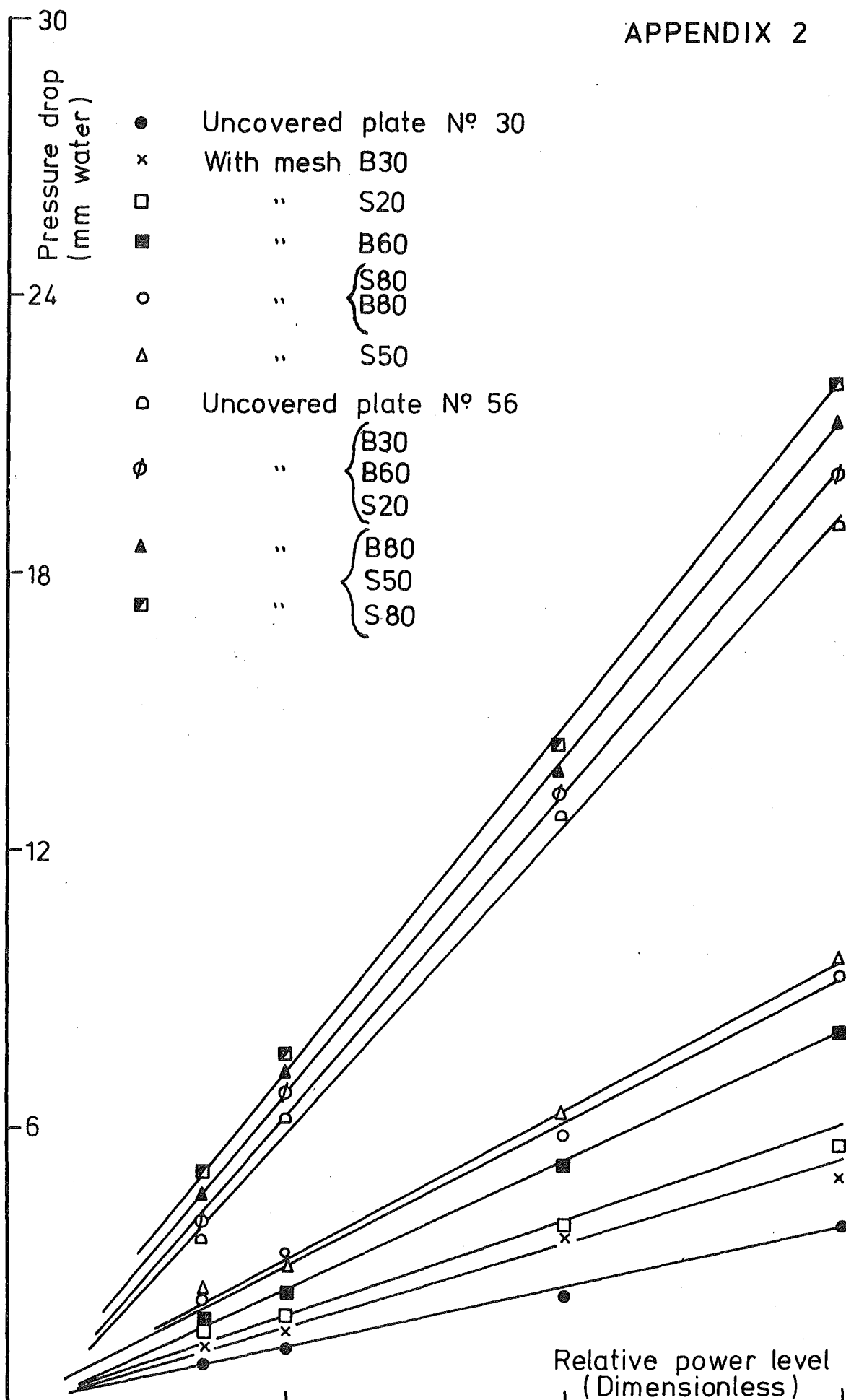


Fig 69 SLIDING FORCE vs PRESSURE N° 24 PLATE

APPENDIX 2



APPENDIX 2

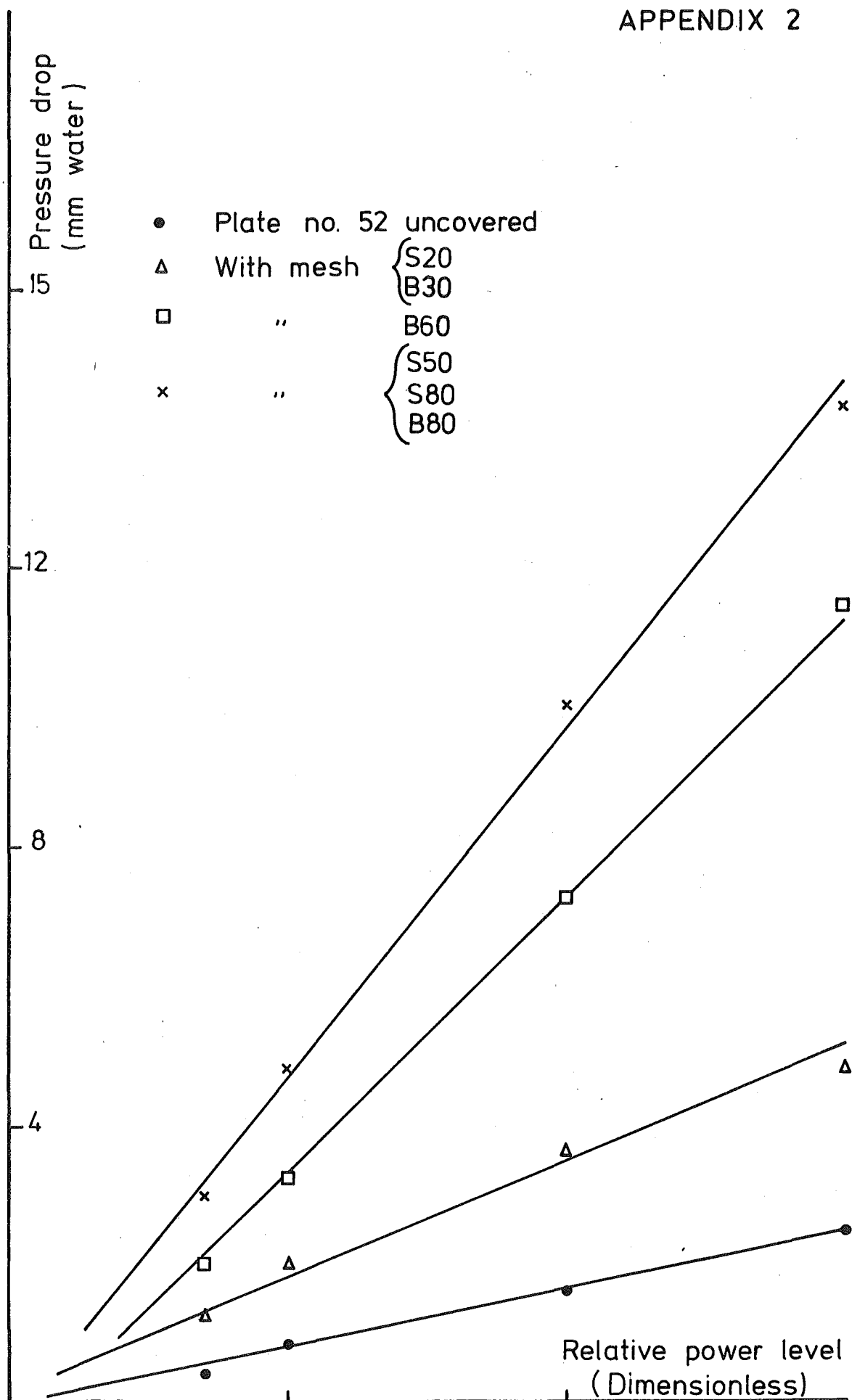


Fig 71 PLATE 52 POWER vs PRESSURE DROP

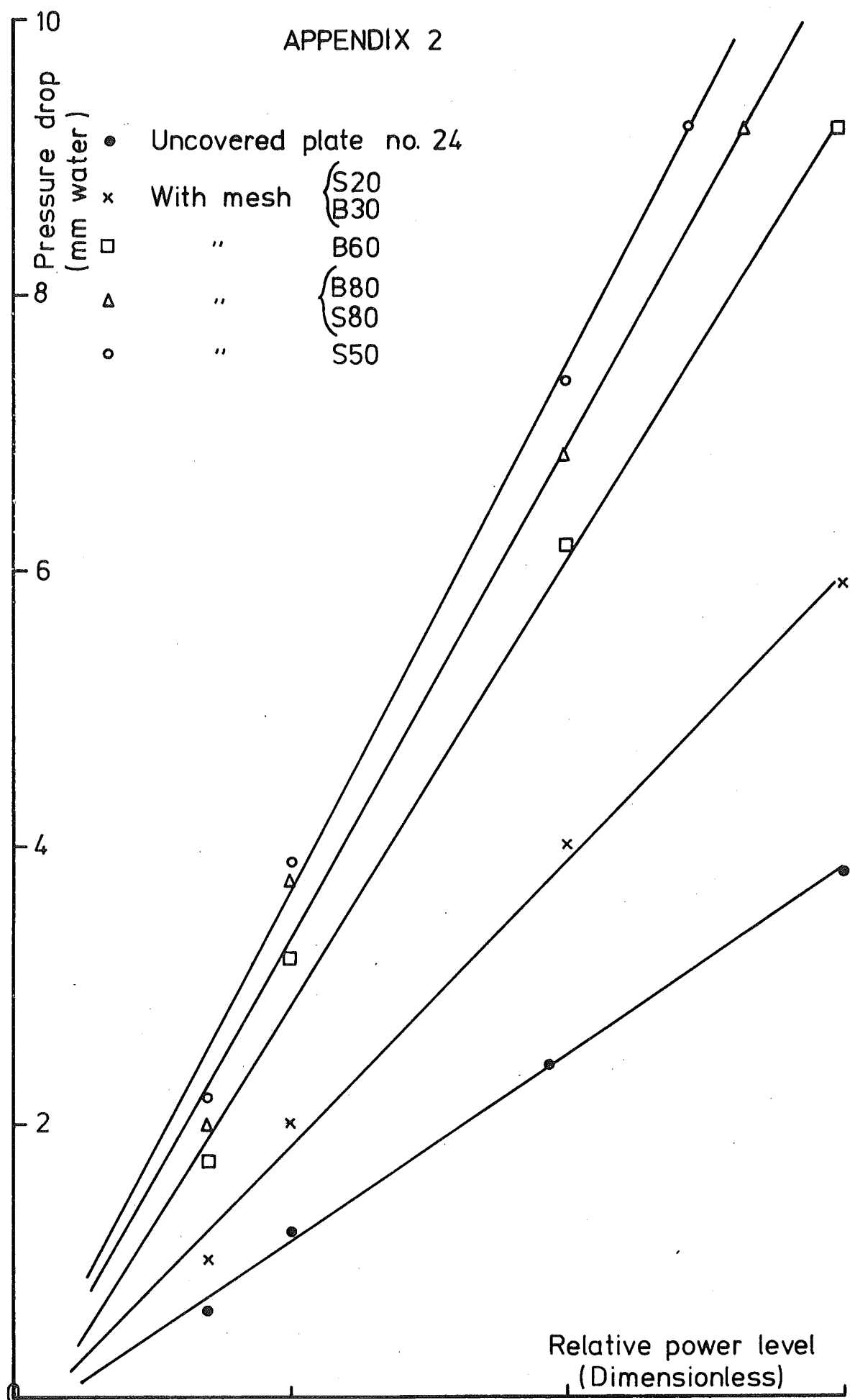


Fig 72 PLATE 24, POWER vs PRESSURE DROP MESH
COVERS

APPENDIX IIIDESIGN CALCULATIONS FOR SUCTION ROLLER(1) INITIAL DESIGN

A pressure drop of four inches water gauge was required across the punched metal plate. Considering the diagram, Figure 73 : Head losses occur at the plate, H_1 , at the entry to the pipe, H_2 , in the pipe H_3 and at the bends, H_4 .

$$H_T = \sum_{i=1}^4 H_i$$

The loss factors, K , were taken from tables³, including the K for punched plate (Figure 73) where K is defined as:

$$K = \frac{H}{VP} \quad (VP \text{ is velocity pressure defined as } \left(\frac{V}{3970}\right)^2 \text{ (V in ft/min)})$$

$$\therefore \sum H = \sum VP K$$

Now, the graph, Figure 73³ K for punched steel plate, of open area

$$= .3$$

$$= 9$$

\therefore As this is desired to be a 4" drop :

$$H_1 = 4 = 9 \times \left(\frac{V}{3970}\right)^2$$

$$\therefore V_1 = \sqrt{\frac{4}{9}} \times 3970 = 2650 \text{ ft/min}$$

The total area of the punched plate

$$= 50 \times 8 \times r \text{ sq.inches}$$

$$= 120 \text{ sq/ins.}$$

The pipe area = 28 sq/ins.

$$\therefore V_2 = 11400 \text{ ft/min.}$$

From tables $H_2 = .5, H_3 = .05, H_4 = .25$

$$\therefore \sum H = 4 + 8.2 \times (.8)$$

$$= 10.6"$$

$$Q = A_2 V_2 = 2200 \text{ ft}^3/\text{min.}$$

Fan tables of Richardson, $3\frac{1}{2}$ VB, show that at 3000 r.p.m., 2200 cfm is delivered at 10" w.g., using 7.90 H.P.

(2) MODIFIED REQUIREMENTS

To produce a 10" pressure drop across the plate,

$$V_1 = 4180 \text{ ft/min}$$

$$V_2 = 18,100 \text{ ft/min}$$

$$\text{and } \sum H = 10 + 20.8 \times .8$$

$$= 26.6"$$

$$Q = 3500 \text{ cfm.}$$

For the reasons outlined in Chapter VII section 8 , it was decided that a Richardson series 4, 29 H.P. model centrifugal fan would be used. This had a maximum capacity of 4000 cfm, maximum static pressure 40" w.g., but required a 50 H.P. motor.

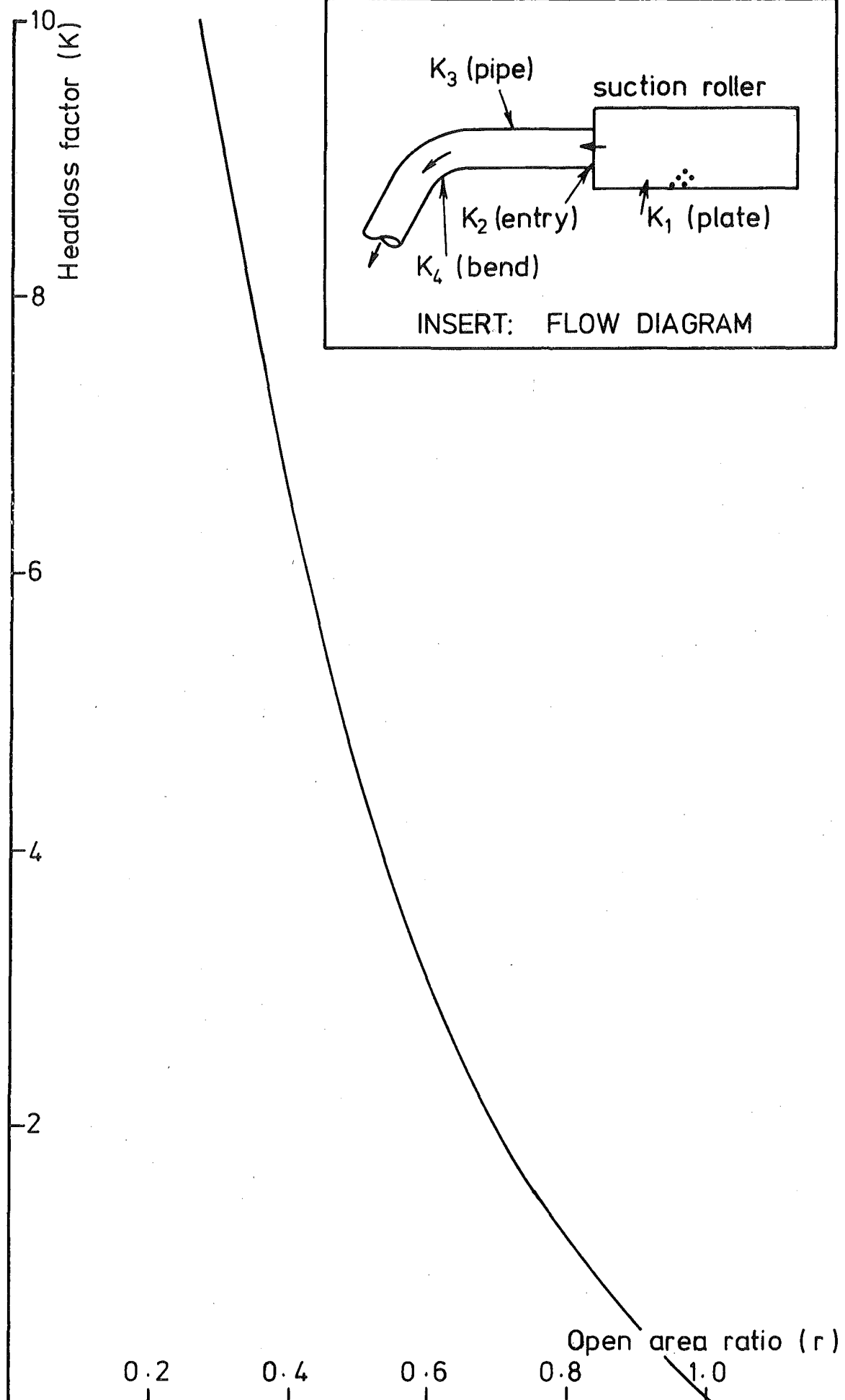


Fig 73 HEADLOSS FACTOR (K) vs OPEN AREA RATIO

APPENDIX IVBANDKNIFE MACHINE MANUFACTURERS

- (1) McNeil Femco
1734 Front Street,
Cuyahoga Falls,
Ohio 44221, U.S.A.
- (2) The Doall Company,
Des Plaines,
Illinois, U.S.A.
- (3) Merger Freres,
Annonay,
FRANCE.

APPENDIX V

DESIGN CALCULATIONS FOR BANDKNIFE WHEELS

(1) Diameter of Wheels: The blade was .055" thick.

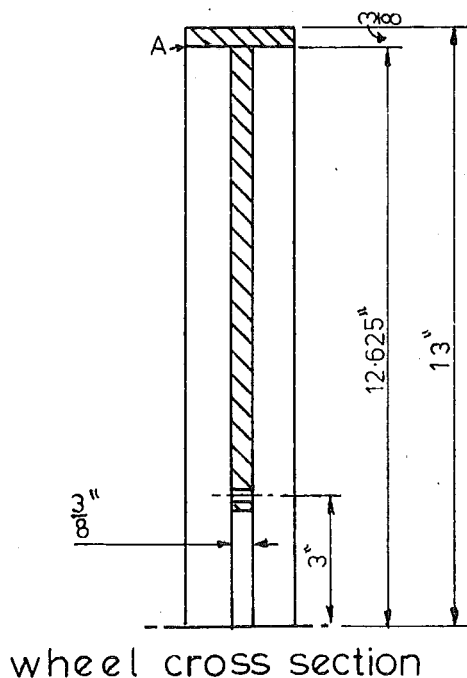
From simple bending theory, for a thin member, the maximum stress in the member, S , of thickness $2y$, bending radius R_1 is given by :

$$S = \frac{Ey}{R}, \text{ or}$$

$$R = \frac{Ey}{S} = 13" \text{ if } S \text{ is taken at } 65,000 \text{ p.s.i.}$$

For the high carbon steel used in bandknife blades this stress was near the fatigue limiting stress. However, as continuous grinding was being carried out on the blade, an infinite fatigue life was not required. Consequently, 26" diameter wheels were constructed.

(2) The wheels were flanged discs, bolted to a stiff boss. The following method for calculating the maximum stress in the wheels assumes that the radial stress is evenly distributed over the thickness of the disc or flange (Ref: Timoshenko⁵).



Referring to the preceding diagram:

At the interface (A), if the radial stress in the disc is P , then the change in stress across the section

$$\Delta P = - \frac{\Delta y}{y + \Delta y} \cdot P$$

where y = original thickness.

Also at section (A) the radial strains of both disc and flange are equal.

Other constants are : At outside radius of flange, the radial stress is zero; at the P.C.D. of the disc restraining bolts, the radial strain is very small and will be regarded as zero.

(a) At $R = 13$, radial stress $P = 0$, i.e.

$$P = 0 = A_1 - \frac{B_1}{(13)^2} - \frac{3m+1}{8m} \frac{\rho \omega^2}{g} \cdot r^2$$

(Equation Ref. 5)

$$\text{giving } A_1 = .0059 B_1 + 5134 \text{ (for steel wheels)}$$

....(1)

(b) At $R = 3$, radial strain is assumed zero, i.e.

$$u = 0 = 3 \left(\frac{m-1}{ME} \right) A_2 + \left(\frac{m+1}{ME} \right) \frac{B_2}{3} - \left(\frac{m^2-1}{m^2 E} \right) \frac{\rho \omega^2}{g} \cdot \frac{r^3}{8}$$

$$\text{giving } A_2 = - .22 B_2 + 110.9.$$

....(2)

(c) At $R = 12.625$, $u_1 = u_2$, i.e.

$$\left(\frac{m-1}{ME} \right) A_1 r + \left(\frac{m+1}{ME} \right) \frac{B_1}{r}$$

$$= \left(\frac{m-1}{ME} \right) A_2 r + \left(\frac{m+1}{ME} \right) \frac{B_2}{r}$$

$$25.25 A_1 + .317 B_1 = 25.25 A_2 + .317 B_2$$

on substituting (a) and (b)

$$B_1 = -11.2 B_2 - 271,513 \quad \dots (3)$$

(d) At section (A),

$$P + \Delta P = P \left(1 - \frac{\Delta y}{y + \Delta y} \right)$$

$$\text{i.e. } A_1 - \frac{B_1}{r_A^2} - Cr_A^2 = \left(A_2 - \frac{B_2}{r_A^2} - Cr_A^2 \right) \times \left(1 - \frac{\Delta y}{y + \Delta y} \right).$$

$$\text{As } y = 3/8, \Delta y = 2\frac{5}{8}, r = 12.625$$

$$A_1 - .0063 B_1 - 4781 = (A_2 - .0063 B_2 - 4781) (.125)$$

On substituting for A_1, A_2

$$B_1 = 70 B_2 + 2,375,000 \quad \dots (4)$$

From (c) and (d) and (b) and (a)

$$A_1 = +5711$$

$$B_1 = +97,900$$

$$A_2 = 7267$$

$$B_2 = -32,530.$$

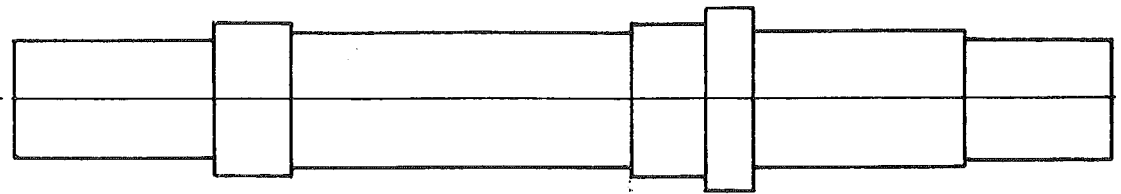
It may be shown that the maximum radial stress in disc occurs at $r = 3$.

$$P_m = 9055 \text{ lb/in}^2, \text{ in rim } P_m = 333 \text{ lb/in}^2$$

and maximum tangential stress

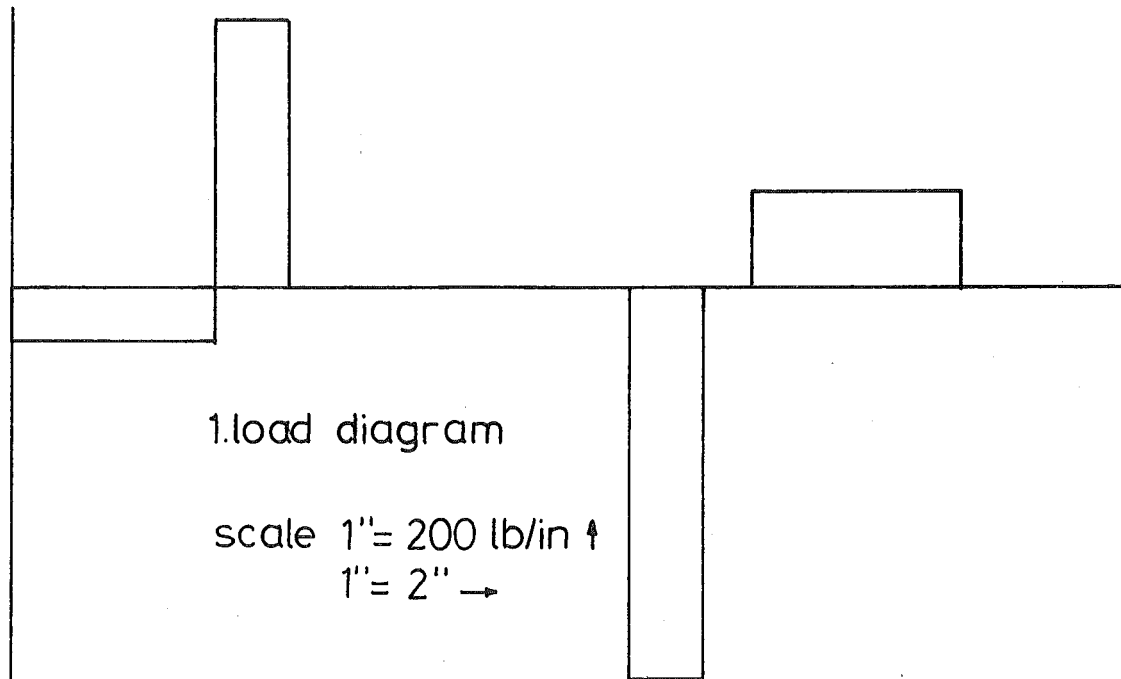
$$\text{disc } q_m = 10,881 \text{ lb/in}^2, \text{ rim } q_m = 3508 \text{ lb/in}^2.$$

These stresses were considered acceptable for steel wheels, but not for cast iron.



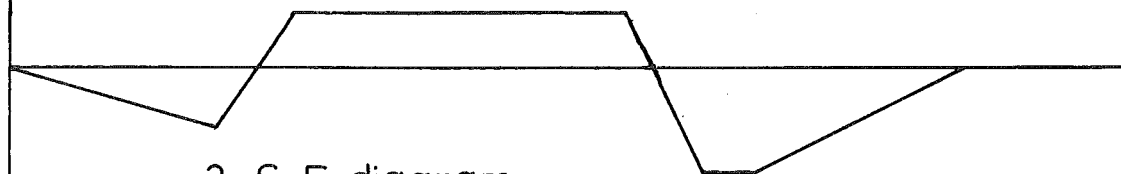
1. load diagram

scale $1'' = 200 \text{ lb/in} \uparrow$
 $1'' = 2'' \rightarrow$



2. S.F. diagram

scale $1'' = 400 \text{ lb}$



3. B.M. diagram

scale $1'' = 1600 \text{ lb.in}$

max = 700 lb.in , $\sigma = 2000 \text{ lb/in}^2$

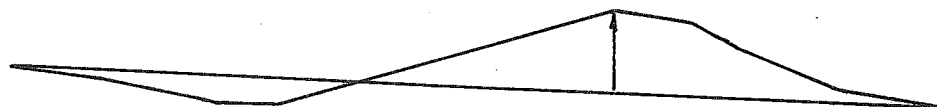


FIG 74 BANDKNIFE SHAFT S.F.+B.M.

APPENDIX VITHE REISE RAW SKIN SHEARING MACHINE

During the course of the project, the existence of an American patent for a raw skin shearing machine was discovered.

In June 1974 the author visited the United States of America primarily to view this raw skin shearing machine developed by Mr O.T. Reise of Milwaukee, Wisconsin. A detailed description of the machine may be found in U.S. Patent No. 3,535,744⁶, and a brief description will be given here.

A diagrammatic representation of the machine is given in Figure 74.

A wire mesh conveyor (A) carried the woolly skin, flesh side down, over a suction chamber (B) around which curved surface the belt ran. A bandknife machine (C) cut the wool from the skin. A ramp, leading from the blade to a plenum chamber (E) formed one side of a duct (D). Air was taken from this plenum chamber and the resulting flow along the duct bent the wool fibres over the blade and carried them into the chamber, depositing them on the conveyor (F). The conveyor carried the cut fleece under a sealing roller to a sorting area.

The author observed a demonstration run of this machine in which salted skins, the only type available, were sheared to a stubble length of $\frac{1}{4}$ to $\frac{3}{8}$ of an inch. Although dry

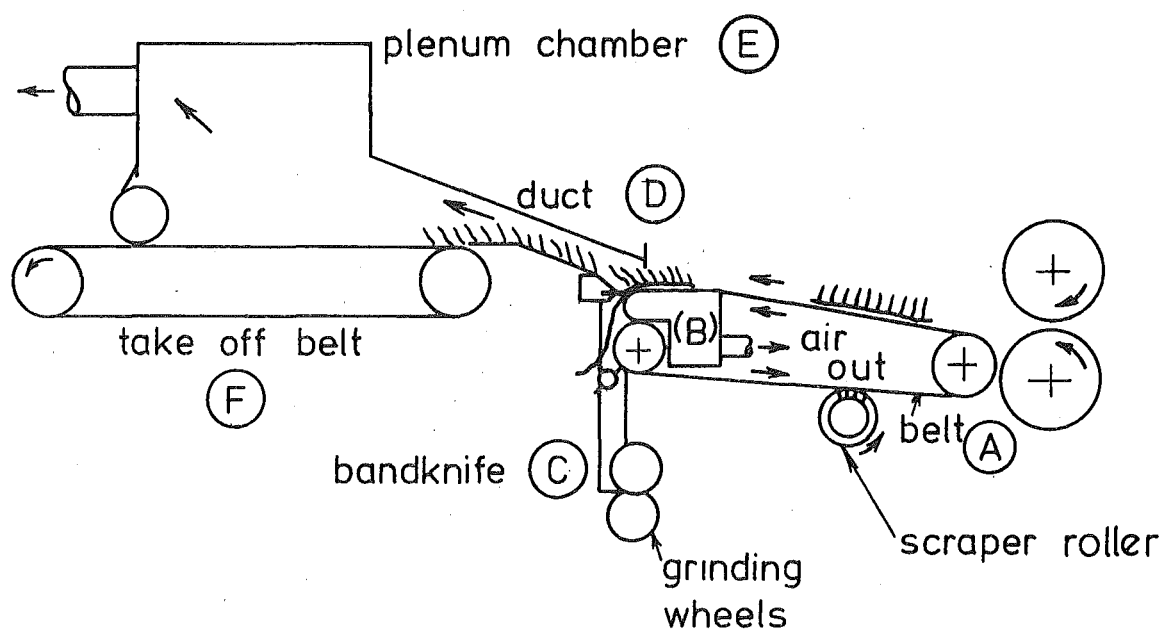


Fig 75 REISE SKIN SHEARING MACHINE

salted skins were more difficult for the machine to hold flat, the problems of skin movement due to the skins' flexibility were not present. Consequently, although the machine was observed to be further advanced than the author's current model (Mark I suction machine), the performance on the raw, damp skins was not known.

The wool removal system, although operator-sensitive, did reliably remove the fleece intact. The bandknife machine was a converted hide splitter and ran at about eighty feet per second. Throughput was low (200 or less per hour) and damage to the skins was not entirely absent.

It was felt that more development work was needed, as this machine was not entirely satisfactory, although it had been undergoing development for 14 years.

APPENDIX VIIALTERNATIVE METHODS OF WOOL REMOVAL

In addition to bandknife cutting of wool from sheepskins, other methods were considered.

One suggestion was that high pressure water jets could be used to remove the wool from the skin. Calculations done by final year Mechanical Design Students showed that the power requirements for this were prohibitive, and the possibility of damage to both wool and pelt was likely.

Laser cutting was considered, but as wool chars, but does not burn, the possibility of damage was high. It was anticipated that laser cutting would be a difficult process to adapt to freezing works conditions.

A proposal, suggested by a Mechanical Engineering Department technician, and investigated by the author, was wool removal by freezing the skin. When the skin temperature was lowered to less than -80° or -100°C , the wool was easily pulled from the skin undamaged. Samples of skin so treated were sent to the New Zealand Leather and Shoe Research Association. Tests conducted there suggested that internal moisture was being frozen and the resultant expansion disrupted the internal structure of the skin, freeing the wool roots. However, as irreversible damage was done to the skin, this investigation was terminated.

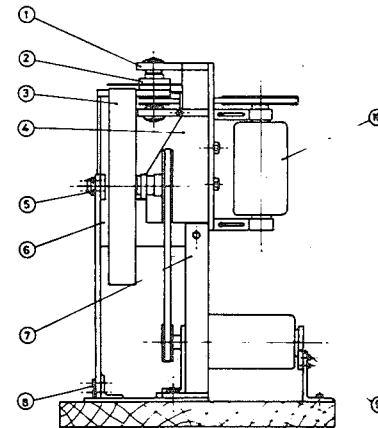
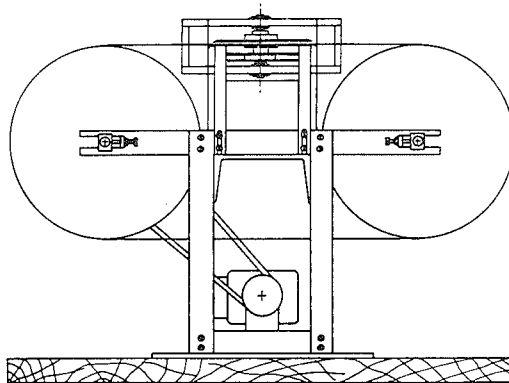
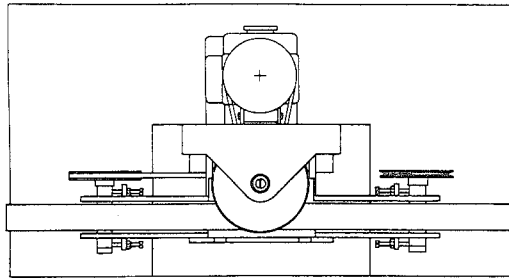
APPENDIX VIIIINDEX TO WORKSHOP DRAWINGS

NOTE: Drawings were numbered from the beginning of each year.

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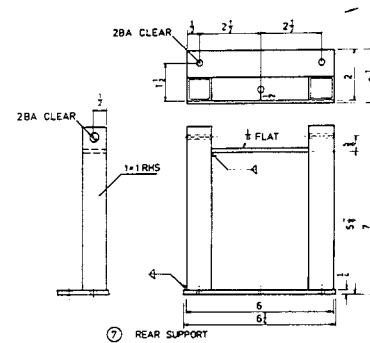
<u>Number Ref.</u>	<u>Title</u>	<u>Page</u>
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4-BS-73	Bandknife Wheels	214
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7-BS-74	End Frame and Rollers for Feed Conveyor	242
8-BS-74	Plenum Chamber and Contraction	244
10-BS-74	Drive Roller and Exit Contraction	245

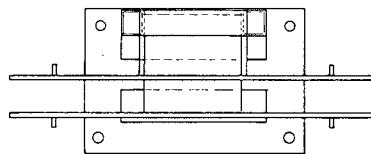


11	Support Table	-	4
10	Dynamometer Assembly	-	2
9	Knife Assembly	-	2
8	Base Plate	-	2
7	Rear Frame	-	2
6	Main Frame	-	2
5	Generator Test Up	-	2
4	Knife Support	-	2
3	Generator Wheel Assembly	-	2
2	Knife Assembly	-	2
1	Knife Support	-	2
ITEM DESCRIPTION		Sheet	2
		NOF	

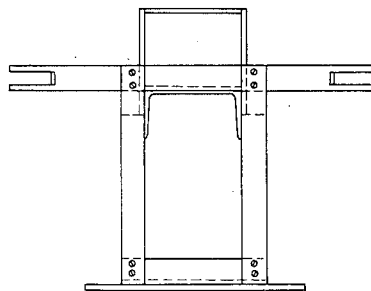
EXPERIMENTAL WOOL CUTTER		SCHOOL OF ENGINEERING MECHANICAL DEPT.	
DRAWN - K. HOSKING		APPROVED -	
TRACED - V. J. GREY		DATE - 5-5-71	
SCALE - 1/4" = 1" FULL SIZE		DRG No 1-BS-71	



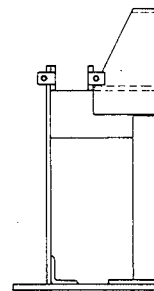
⑥ CONVEYOR WHEELS SUPPORT



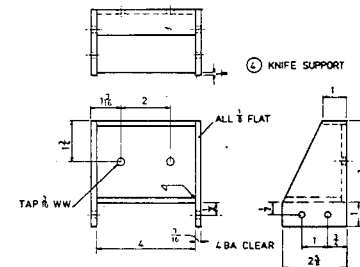
(6a) FRONT SUPPORT



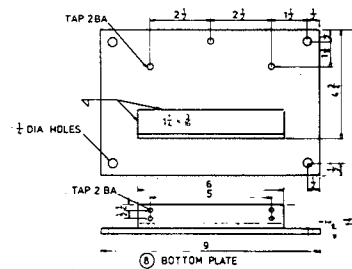
FRAME , ASSEMBLY



④ KNIFE SUPPORT



⑧ BOTTOM PLATE



ALL DIMENSIONS IN INCHES.

TOLERANCES DECIMALS = .002

FRACTIONS: $\frac{1}{2}$ UNLESS IND

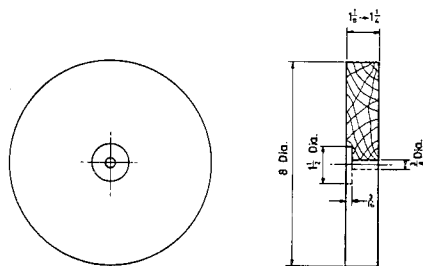
SCALE HALF FULL SIZE

WOOL CUTTER
FRAME DETAILS

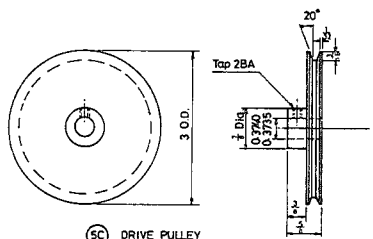
SCHOOL OF ENGINEERING
MECHANICAL DEPT

DRAWN K HOSKING

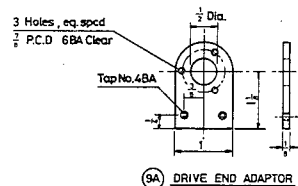
DRG NO 2 BS 71



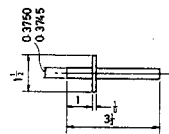
③ CONVEYOR WHEELS 1/2 Full size
Material: Coreboard (Supplied)



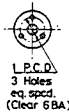
⑤C DRIVE PULLEY



⑧A DRIVE END ADAPTOR



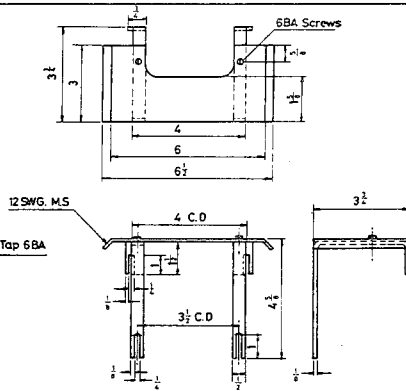
③A SHAFT 1/2 Full size



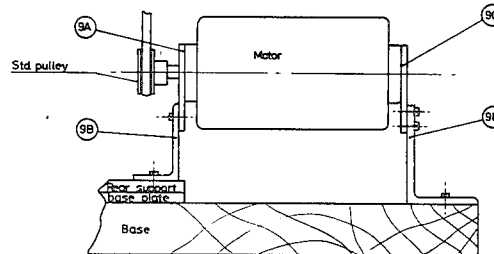
⑤A SLIDER Full size



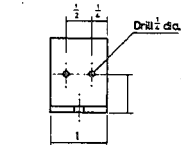
⑤B COLLAR Full size



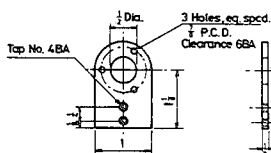
③B SUPPORT TABLE



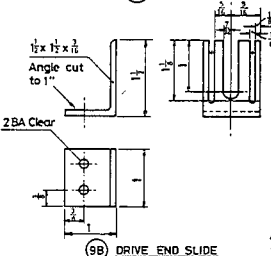
⑨ CONVEYOR DRIVE ASSEMBLY



⑨D IDLER END SLIDE



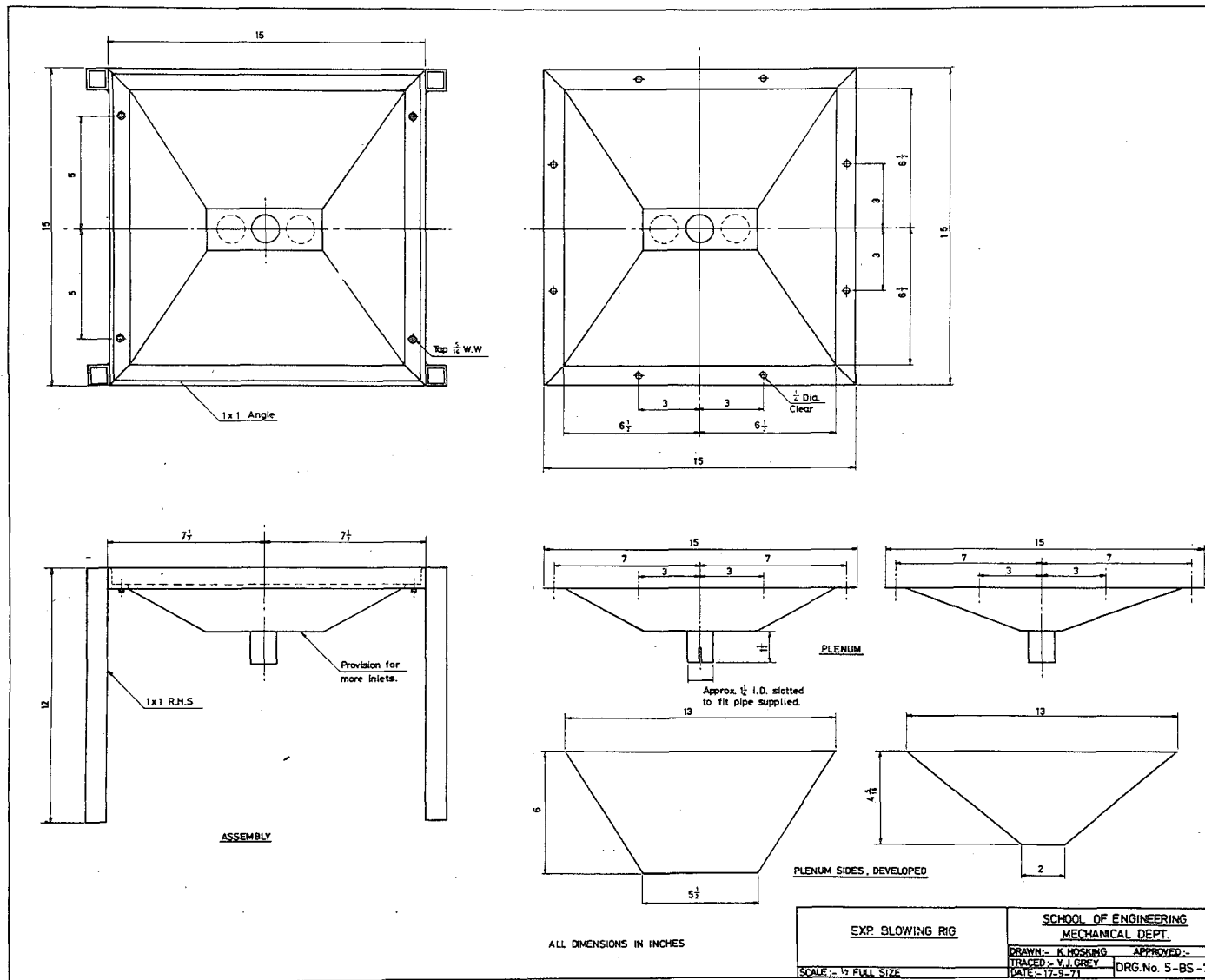
⑨C IDLER END ADAPTOR



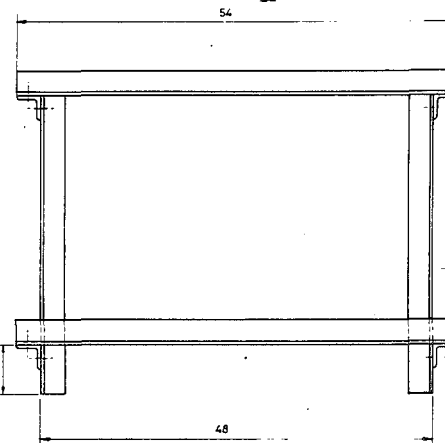
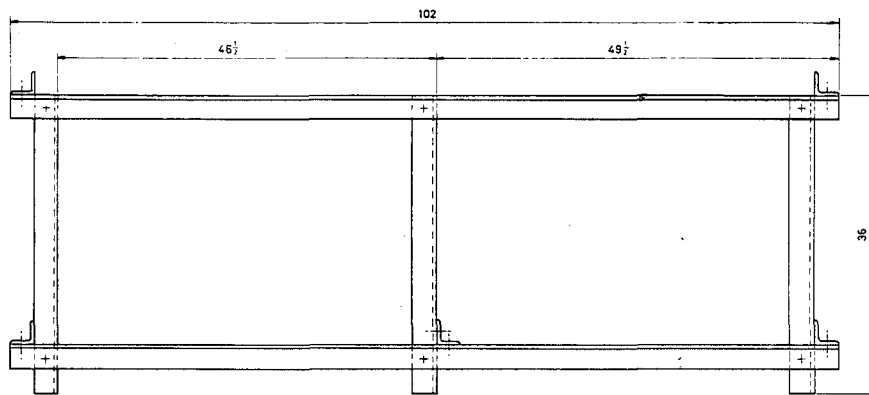
⑨B DRIVE END SLIDE

ALL DIMENSIONS IN INCHES
TOLERANCES :-
- DECIMALS ± 0.002
- FRACTIONS $\pm \frac{1}{16}$
WARNING: DO NOT SCALE

<p>WOOL CUTTER DETAILS - 3RD ANGLE</p>	<p>SCHOOL OF ENGINEERING MECHANICAL DEPT.</p>
<p>SCALE: AS INDICATED</p>	<p>DATE: 5-4-71</p>

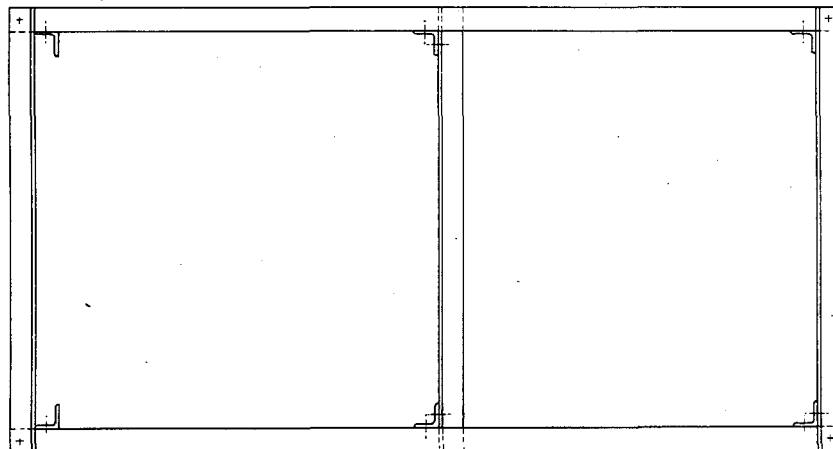




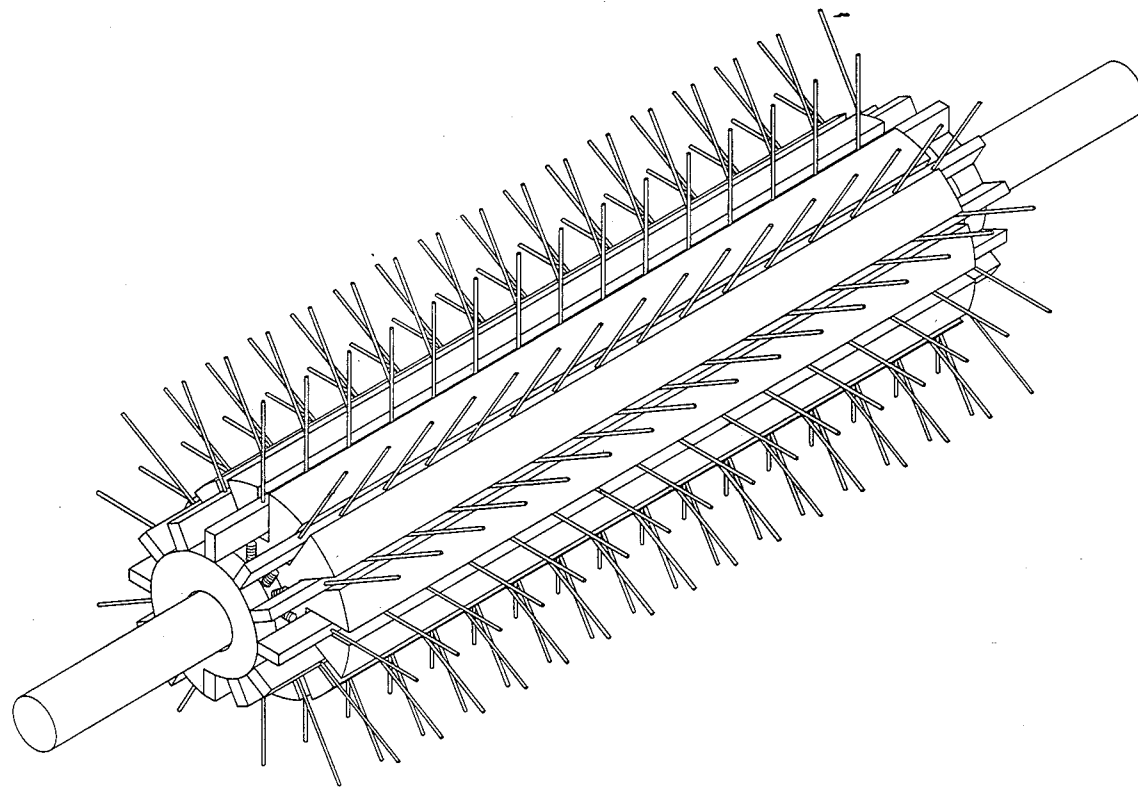


ALL JOINTS BOLTED

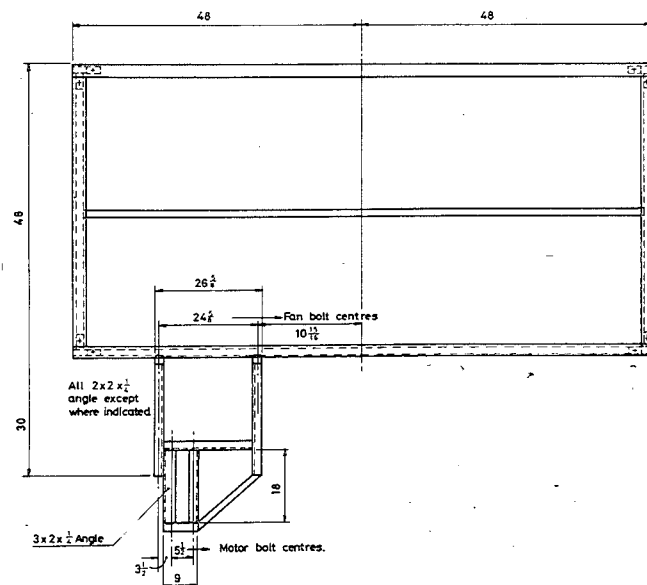
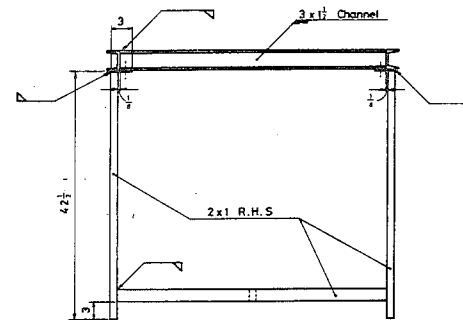
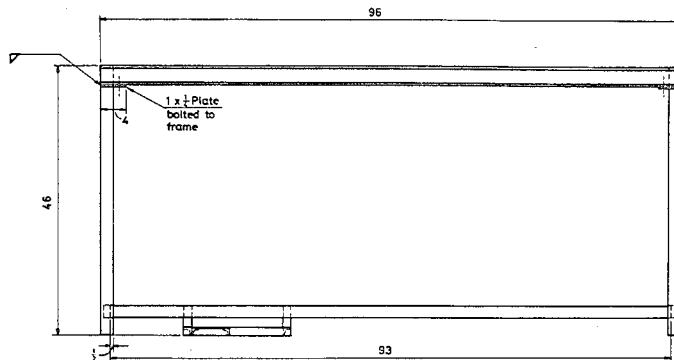
ALL DIMENSIONS IN INCHES



UNIVERSAL CONVEYOR TEST RIG		SCHOOL OF ENGINEERING MECHANICAL DEPT.	
DRAWN - K. HOSKING		APPROVED -	
TRACED - V. J. GREY		DRG No 7-BS-71	
SCALE - 1/4" FULL SIZE		DATE - 4-11-71	

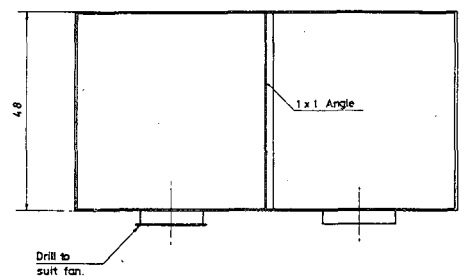
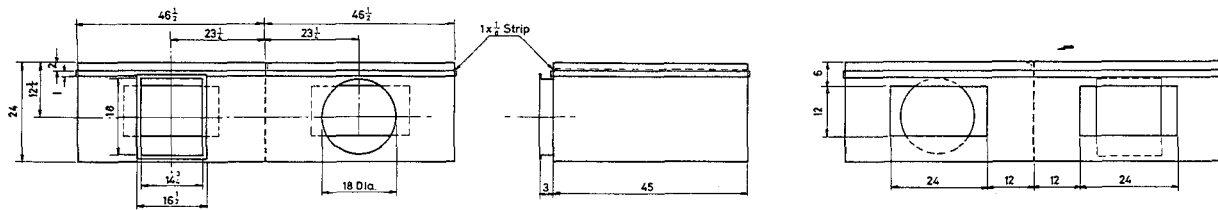


CAM OPERATED SPIKED ROLLER	SCHOOL OF ENGINEERING MECHANICAL DEPT	
	DRAWN K.F. HOSKING	
SCALE FULL SIZE	TRACED J. RITCHIE	DRG N° 8-BS-71
	DATE 20.2.76	

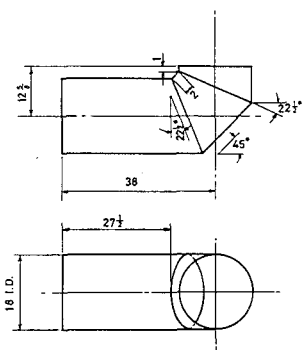


ALL DIMENSIONS IN INCHES

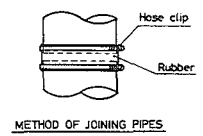
WOOL HANDLING	SCHOOL OF ENGINEERING
RIG FRAME	MECHANICAL DEPT.
SCALE - 1/4" FULL SIZE	DRAWN - K. HOSKINS TRACED - V. J. GREY DATE - 26.10.71 APPROVED - DRG. No 9-BS-71



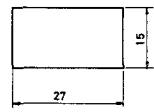
PLENUM CHAMBER
18 S.W.G. Steel



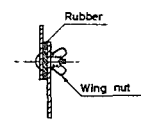
CONNECTING DUCT
18 S.W.G. Steel



METHOD OF JOINING PIPES



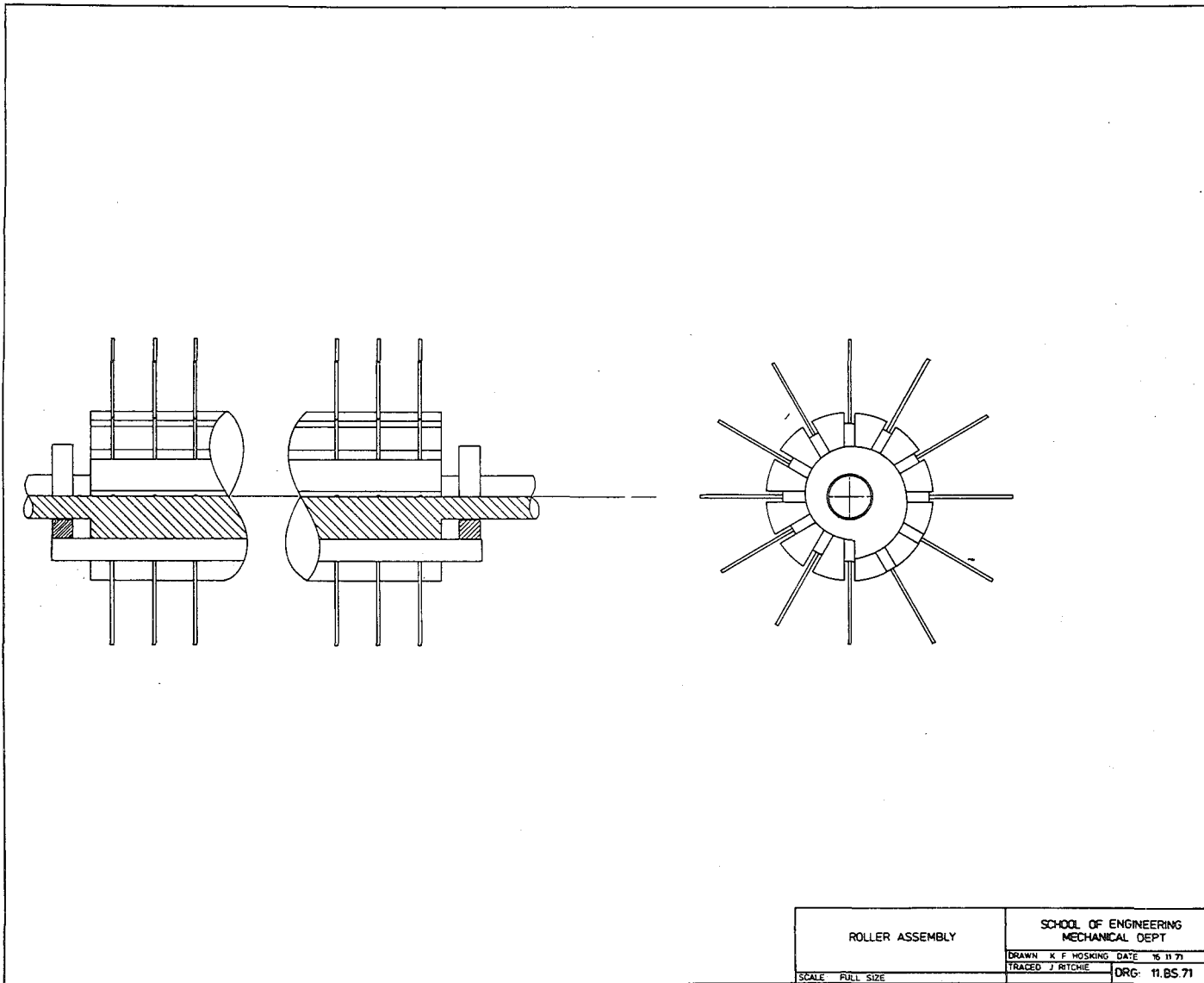
INSPECTION PANEL
(18 S.W.G.)

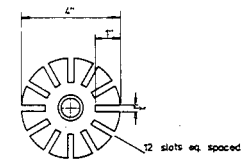


INSPECTION PANEL
FASTENING (N.T.S.)

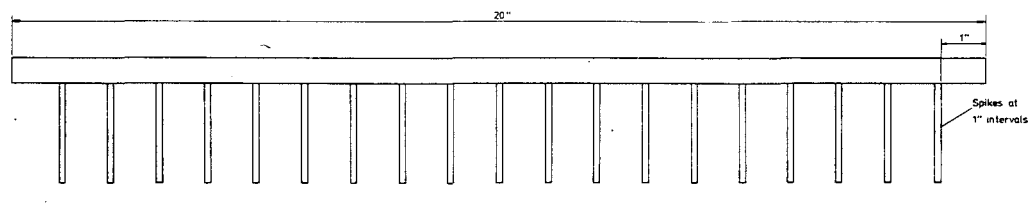
ALL DIMENSIONS IN INCHES

FLEECE HANDLING RIG, PLENUM CHAMBER		SCHOOL OF ENGINEERING MECHANICAL DEPT.	
DRAWN - K. ROSKINS		APPROVED -	
TRACED - V.J. GREY		DATE - 27-11-71	
SCALE - 1in. to 1ft.		DRG. No. 10-BS-71	

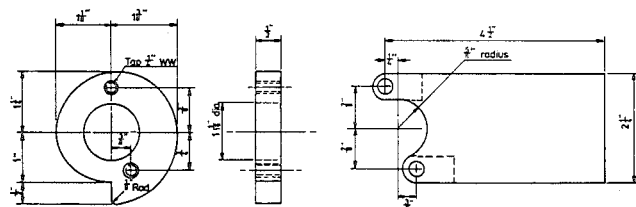




SLOTTED ROLLER: HALF FULL SIZE

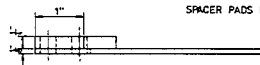


COMBS: FULL SIZE (12 OFF)



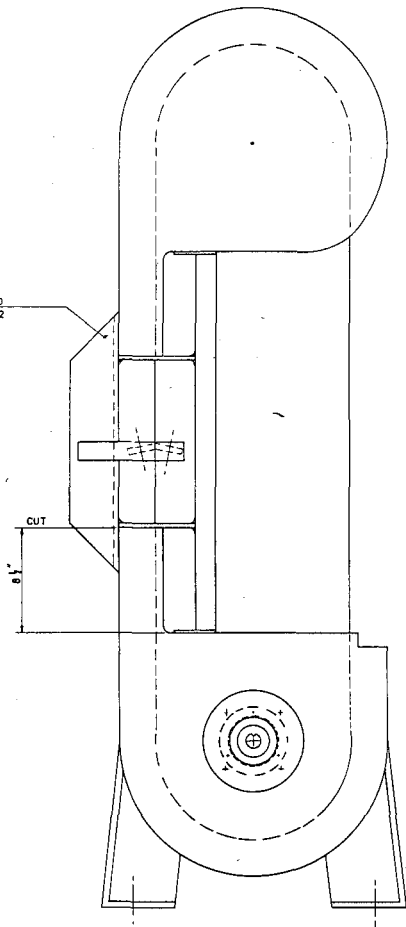
CAM: FULL SIZE (2 OFF)

CAM BRACKET (LHS)
RHS AS ABOVE BUT
SPACER PADS REVERSED

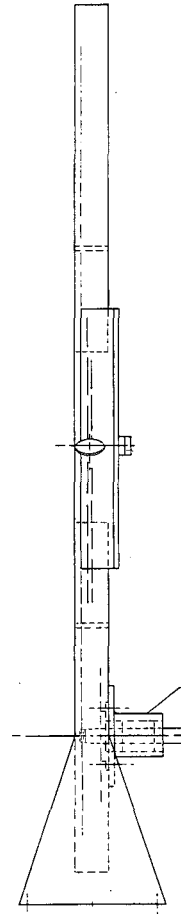


ROLLER DETAILS	SCHOOL OF ENGINEERING MECHANICAL DEPT	
	DRAWN K F MOSKING TRACED J RITCHIE	DATE 12/11/71 DRG NO 12 BS 7
SCALE AS INDICATED		

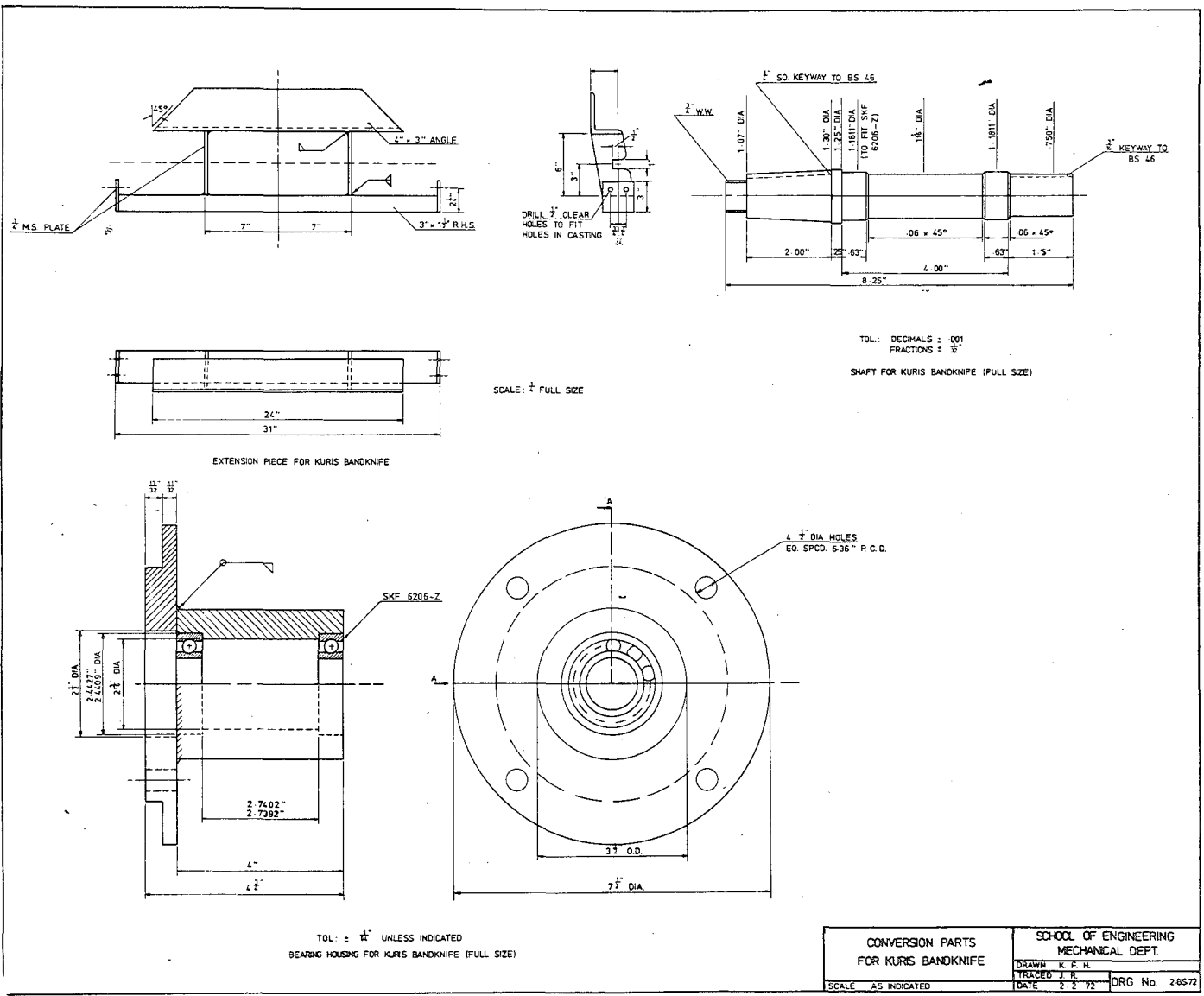
FOR DIMENSIONS OF INSERTED
STRUCTURE SEE DRG 2 BS 72

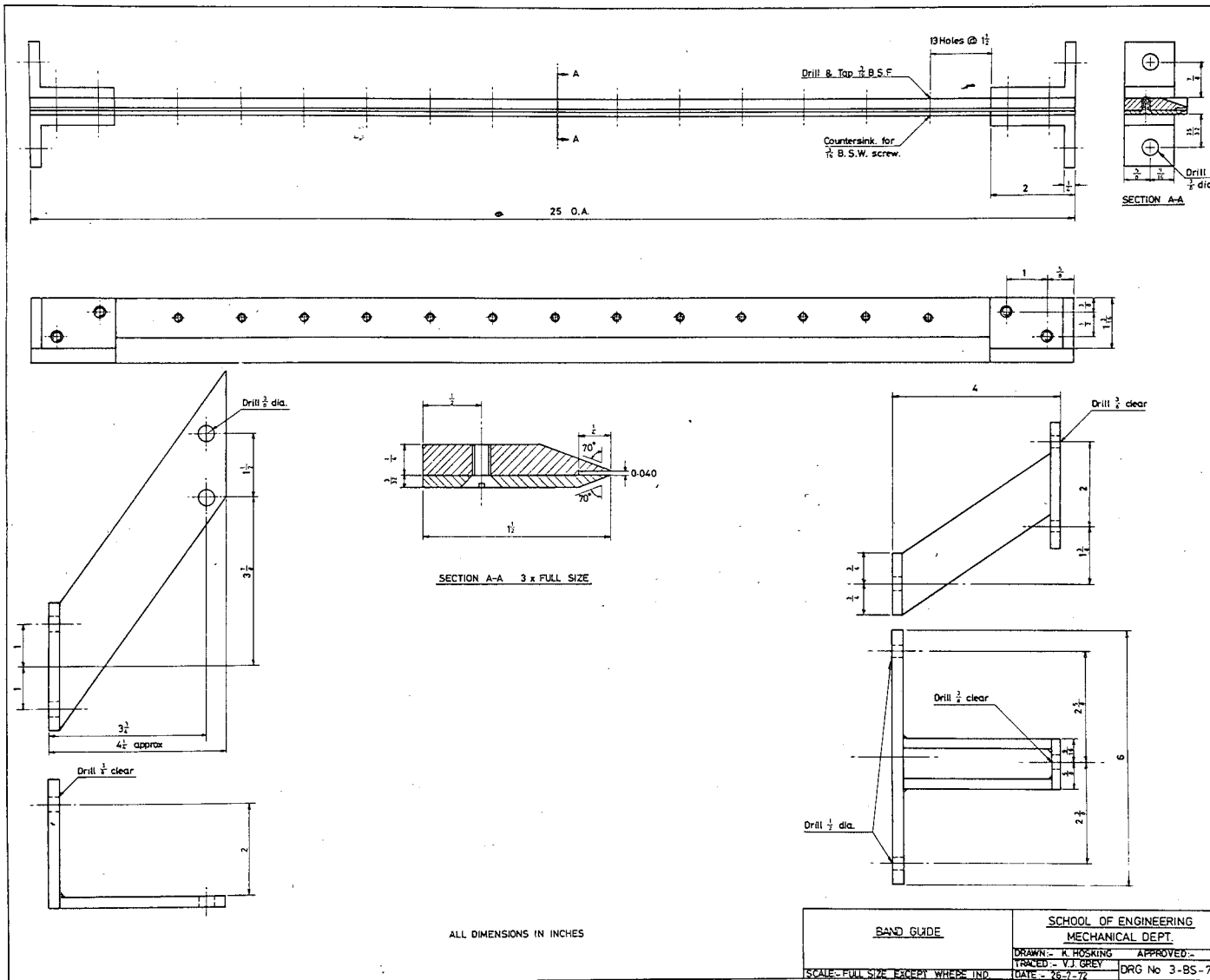


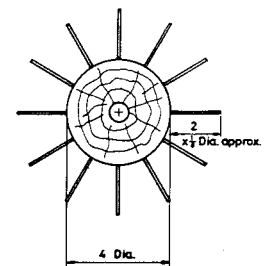
FOR DIMENSIONS OF BEARING
HOUSING SEE 2 BS 72



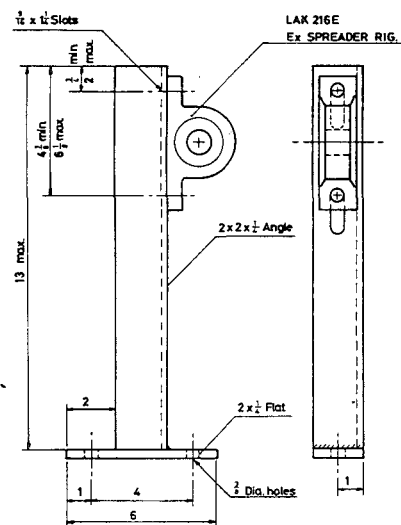
BAND KNIFE MODIFICATIONS	SCHOOL OF ENGINEERING MECHANICAL DEPT	
	DRAWN: K. F. WOSKING	
	TRACED: J. RITCHIE	
SCALE: 1/4" FULL SIZE	DATE: 2-7-72	DRG No 18572



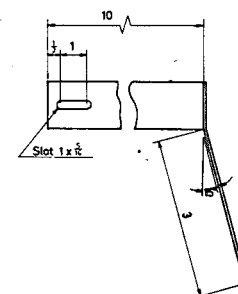
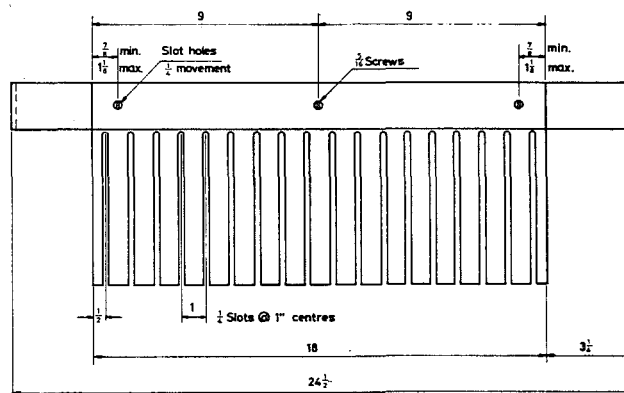




AUXILIARY ROLLER



BEARING SUPPORT (2)



ALL DIMENSIONS IN INCHES

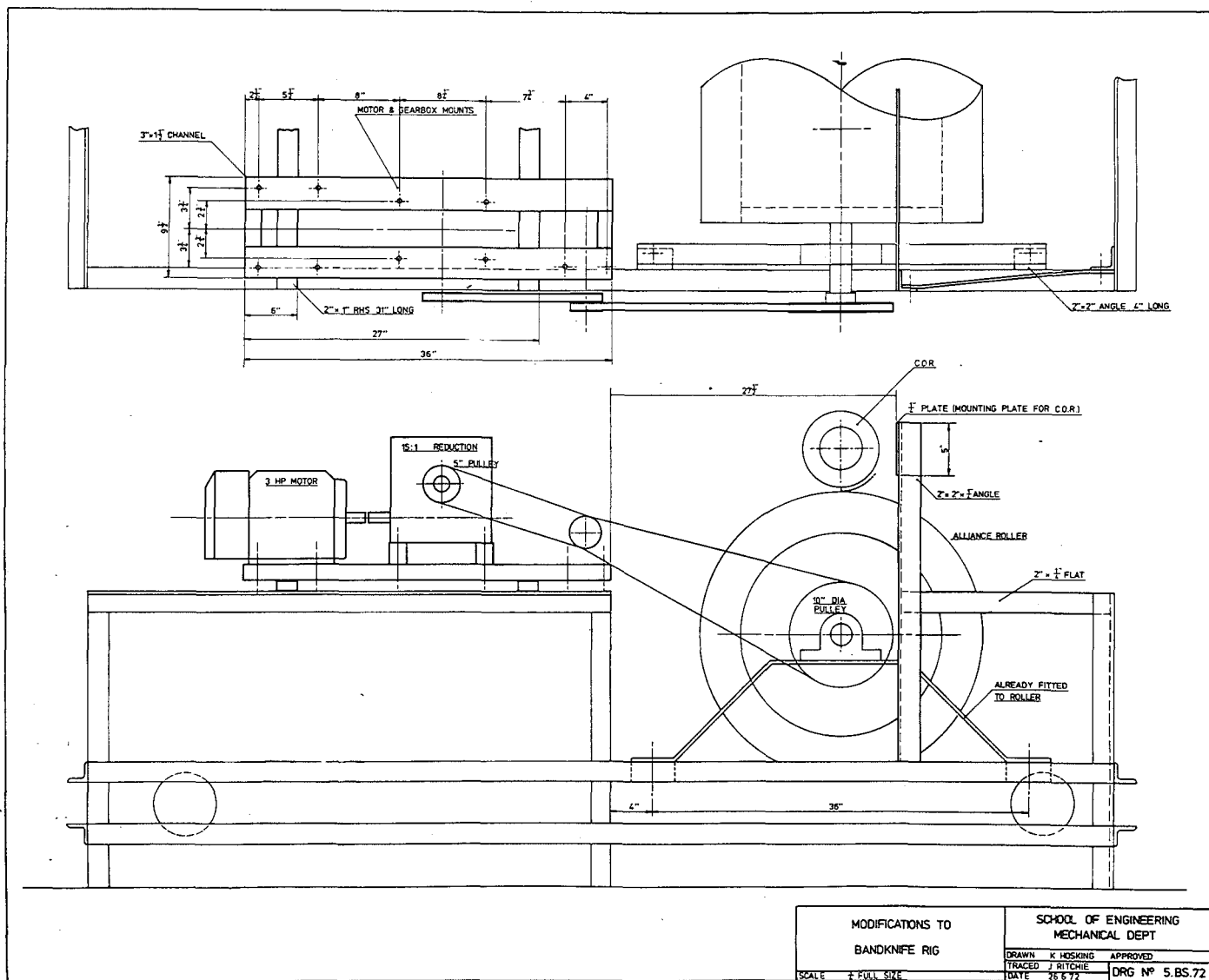
CAM OPERATED ROLLER MODIFICATIONS

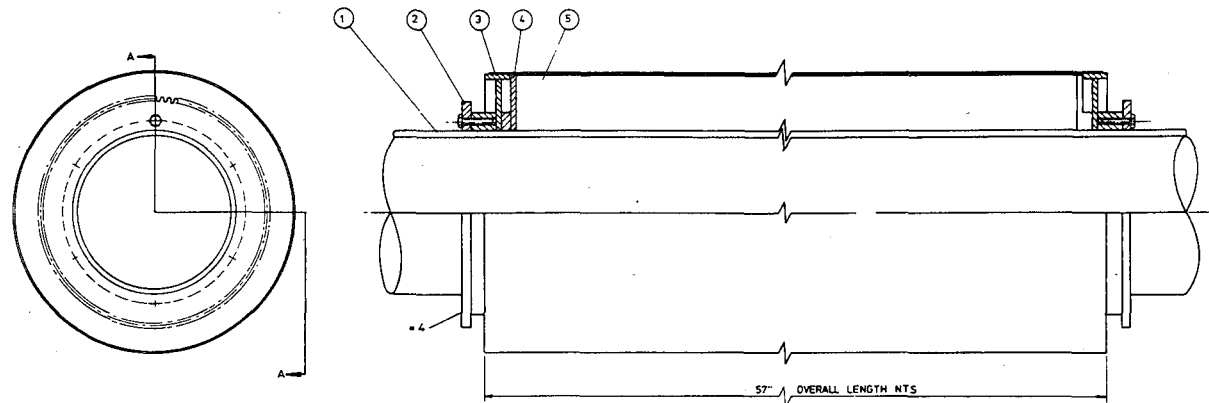
SCALE:- 1/4" FULL SIZE

SCHOOL OF ENGINEERING
MECHANICAL DEPT.

DRAWN:- K. HOSKING
TRACED:- V. J. GREY
DATE:- 16-5-72

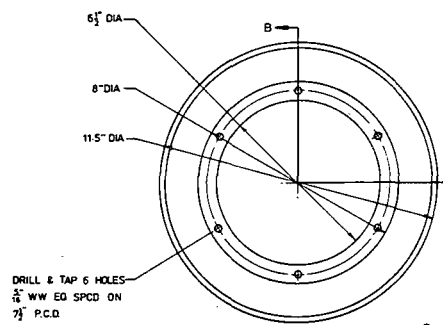
APPROVED: _____
DRG. No. 4-BS-72



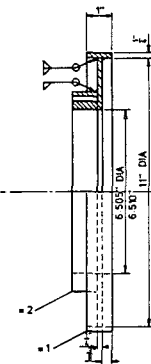


SUCTION DRUM ASSEMBLY

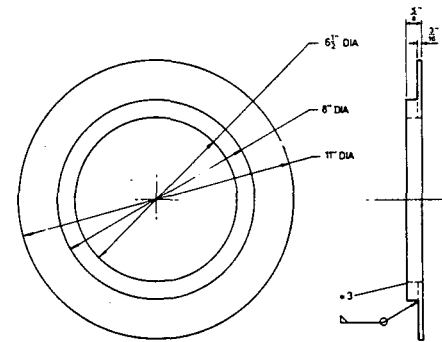
SECTION AA



③ END PLATE (2)



SECTION BB



② BAFFLE PLATE (2)

NOTES

- #1 1" x 1/2" FLAT ROLLER TO 11" I.D.
- #2 MACHINE FROM CYLINDER SUPPLIED
- #3 " " " "
- #4 MACHINE CENTRE FROM SPROCKET TO 6 1/2" DIA

5	2	BAFFLE PLATES	MS
4	2	BAFFLE PLATES	MS
3	2	END PLATES	MS
2	2	57 x 5" x .005" SPROCKET	MS
1	1	6" I.D. STEAM PIPE 1/2" THICK	MS
ITEM NO.		DESCRIPTION	MAT

SUCTION DRUM

SCHOOL OF ENGINEERING
MECHANICAL DEPT

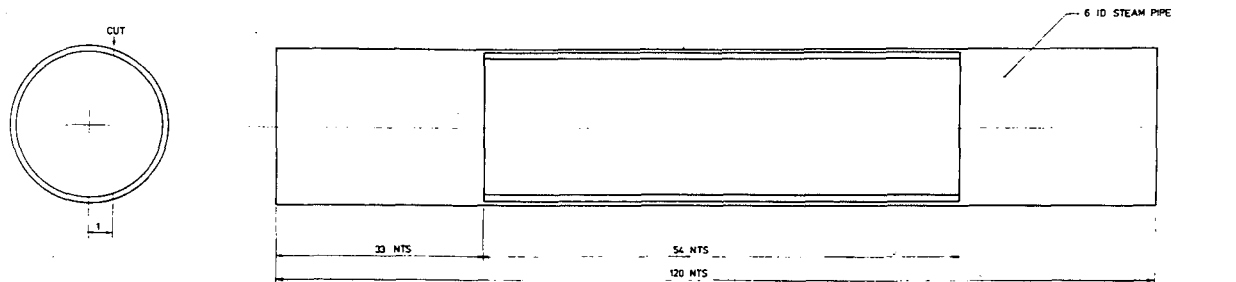
DRAWN K.F.H.

TRACED J.R.

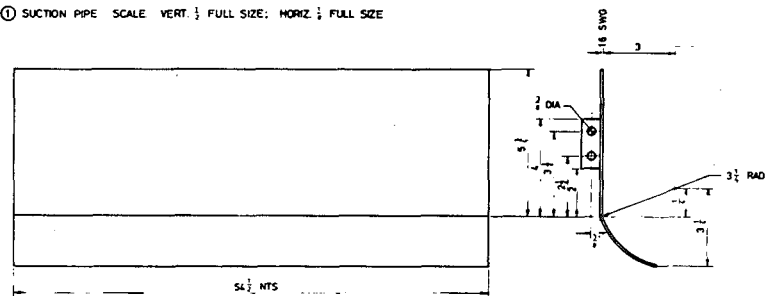
DATE 5.30.72

DRG No. 6.BS.72

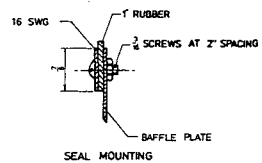
SCALE HALF FULL SIZE



① SUCTION PIPE SCALE VERT. $\frac{1}{2}$ FULL SIZE; HORIZ. $\frac{1}{2}$ FULL SIZE

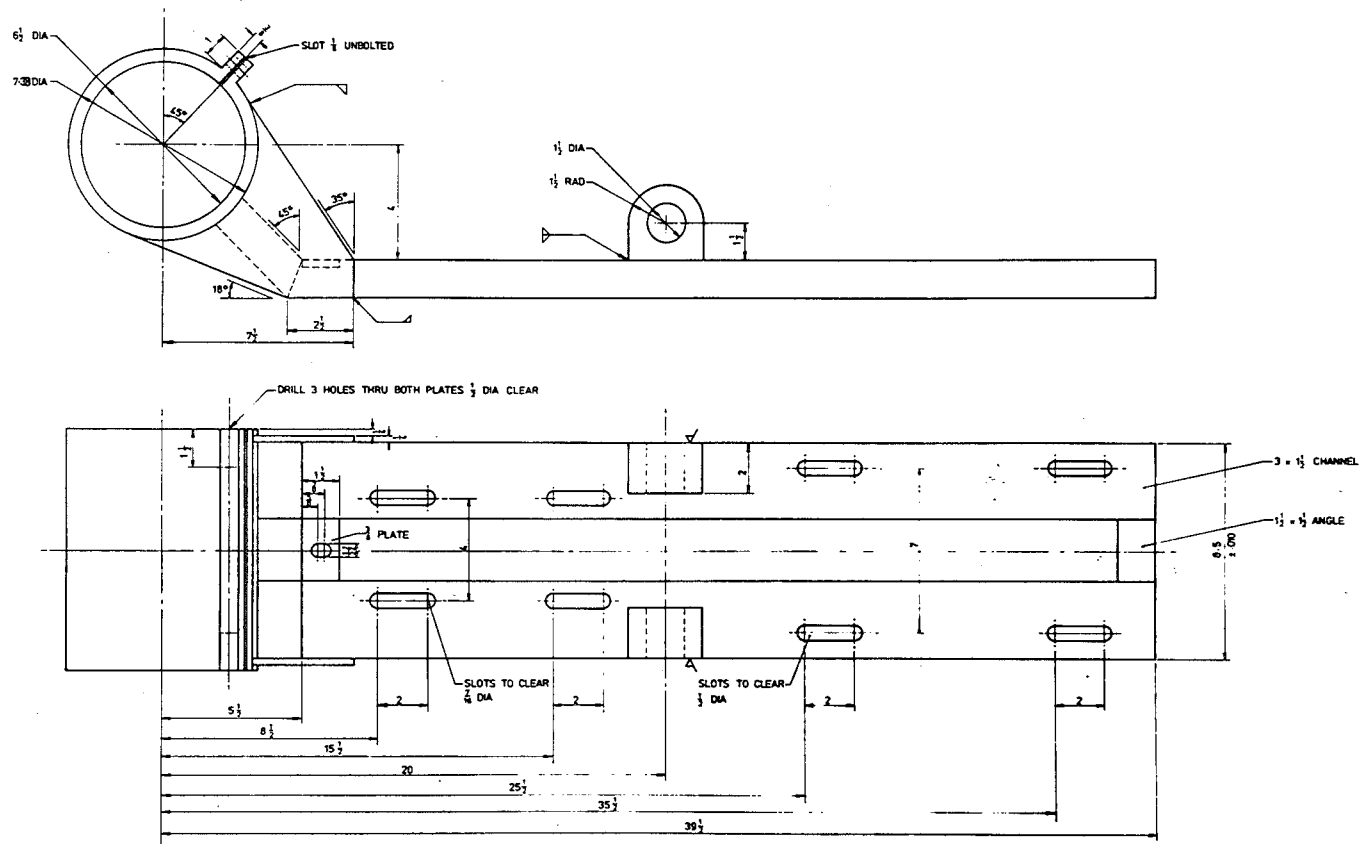


⑤ BAFFLE PLATES (16 SWG SEE SEAL MOUNTING ALSO)
SCALE: AS FOR ①

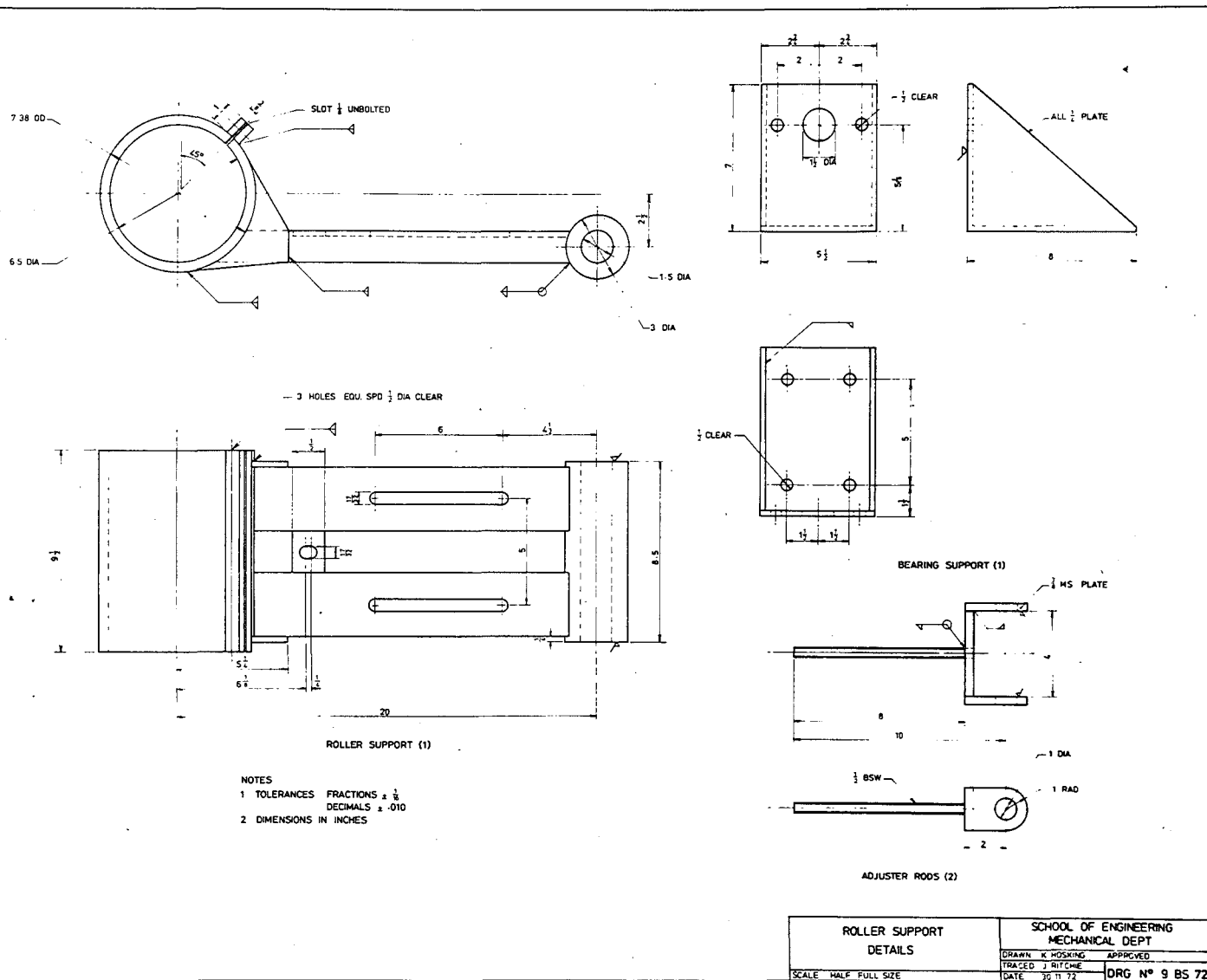


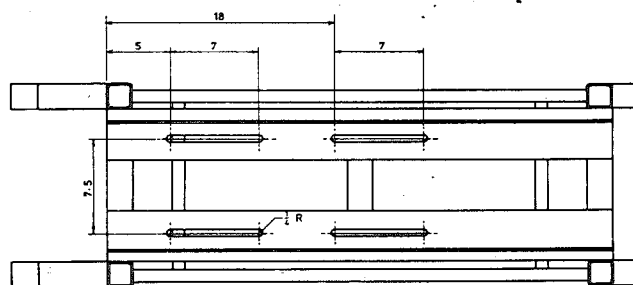
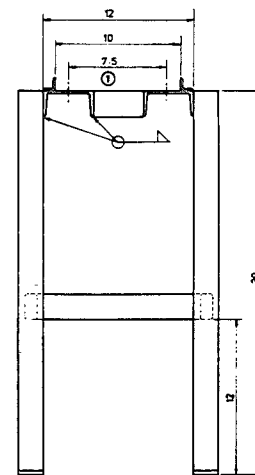
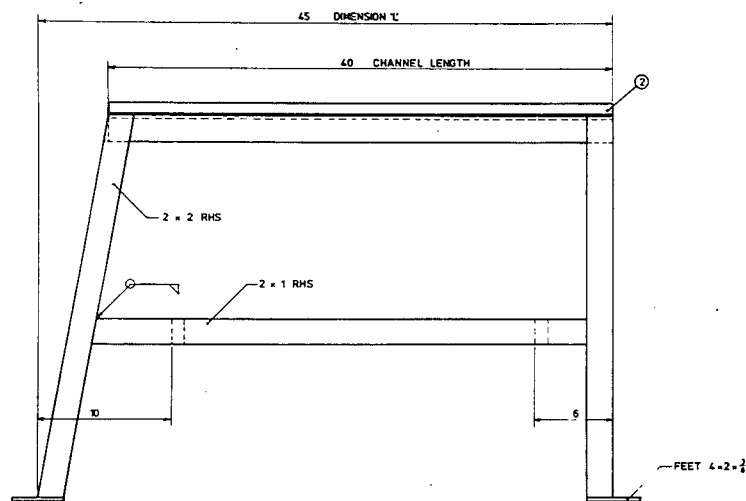
- NOTE
- 1 VERTICAL & HORIZONTAL SCALES DIFFERENT
 - 2 TOLERANCES: FRACTIONS $\pm \frac{1}{16}$
DECIMALS $\pm .010$
 - 3 DIMENSIONS IN INCHES

SUCTION ROLLER DETAILS	SCHOOL OF ENGINEERING	
	MECHANICAL DEPT	
	DRAWN K. HOSKING	
	TRACED J. HOSKING	
SCALE AS INDICATED	DATE 5.12.72	ORG N° 7.BS.72



ROLLER & DRIVE SUPPORT	SCHOOL OF ENGINEERING	
	MECHANICAL DEPT	
	DRAWN K F MOSKOW	APPROVED
	TRACED J RITCHIE	DATE 8.11.72
SCALE HALF FULL SIZE	DRG Nº 8.BS.72	





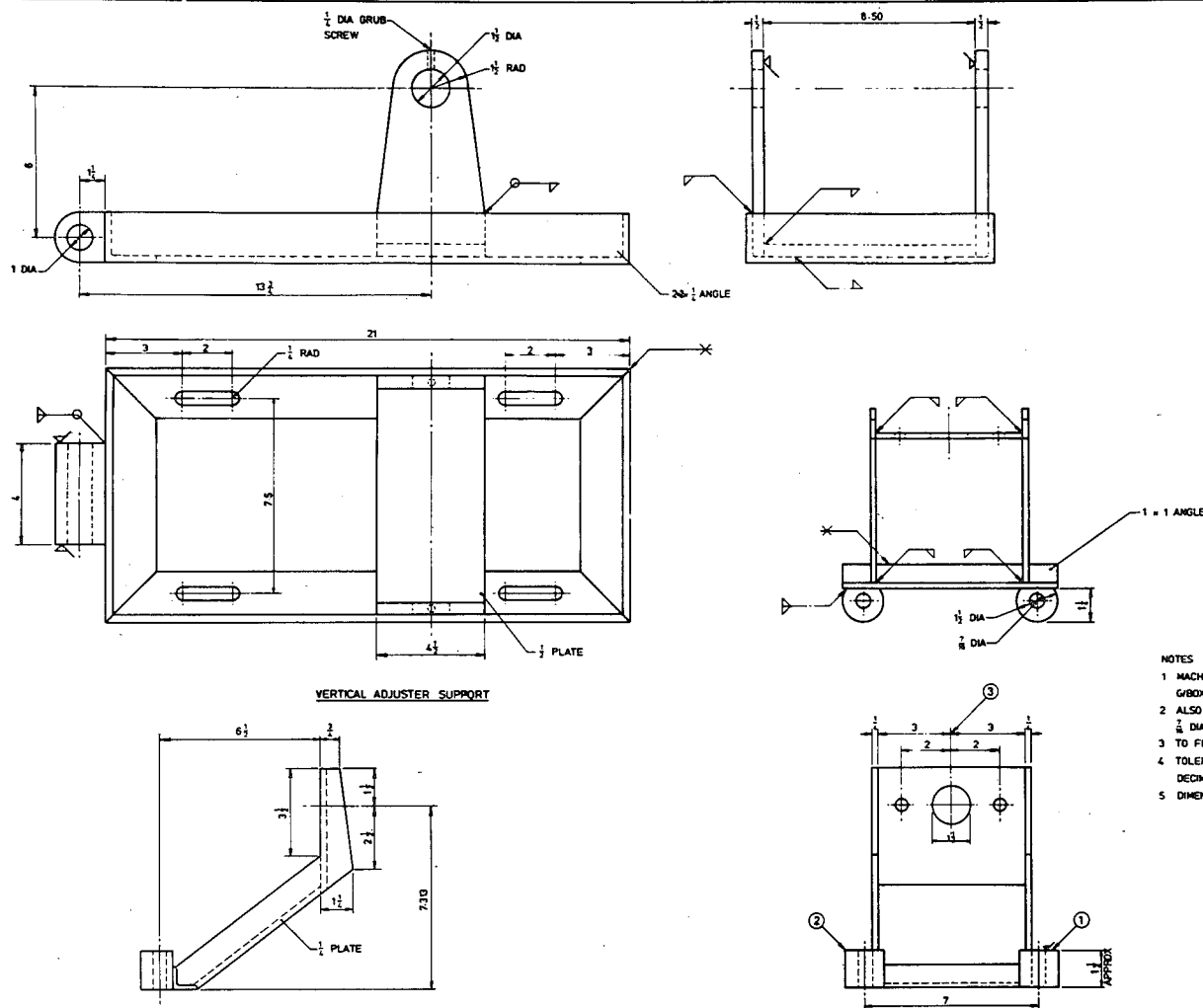
DRIVE SIDE ROLLER SUPPORT ③

NOTES

- 1 TO FIT VERTICAL ADJUSTER SUPPORT DRG 9-B5-72
- 2 1" x 1" ANGLE HELD WITH 4 EQU SPCD $\frac{1}{2}$ " BOLTS
- 3 IDLER SIDE ROLLER SUPPORT IS IDENTICAL EXCEPT THE CHANNELS ARE 30" LONG AND THE OVERALL LENGTH 1' IS 35"
- 4 TOLERANCES FRACTIONS $\pm \frac{1}{8}$
DECIMALS $\pm .010$

DRIVE SIDE ROLLER SUPPORT	SCHOOL OF ENGINEERING MECHANICAL DEPT
DRAWN K HOSKING	APPROVED
TRACED J RYCHKE	
DATE 20.11.72	DRG N° 10-B5-72

SCALE 1/4" = 1" FULL SIZE

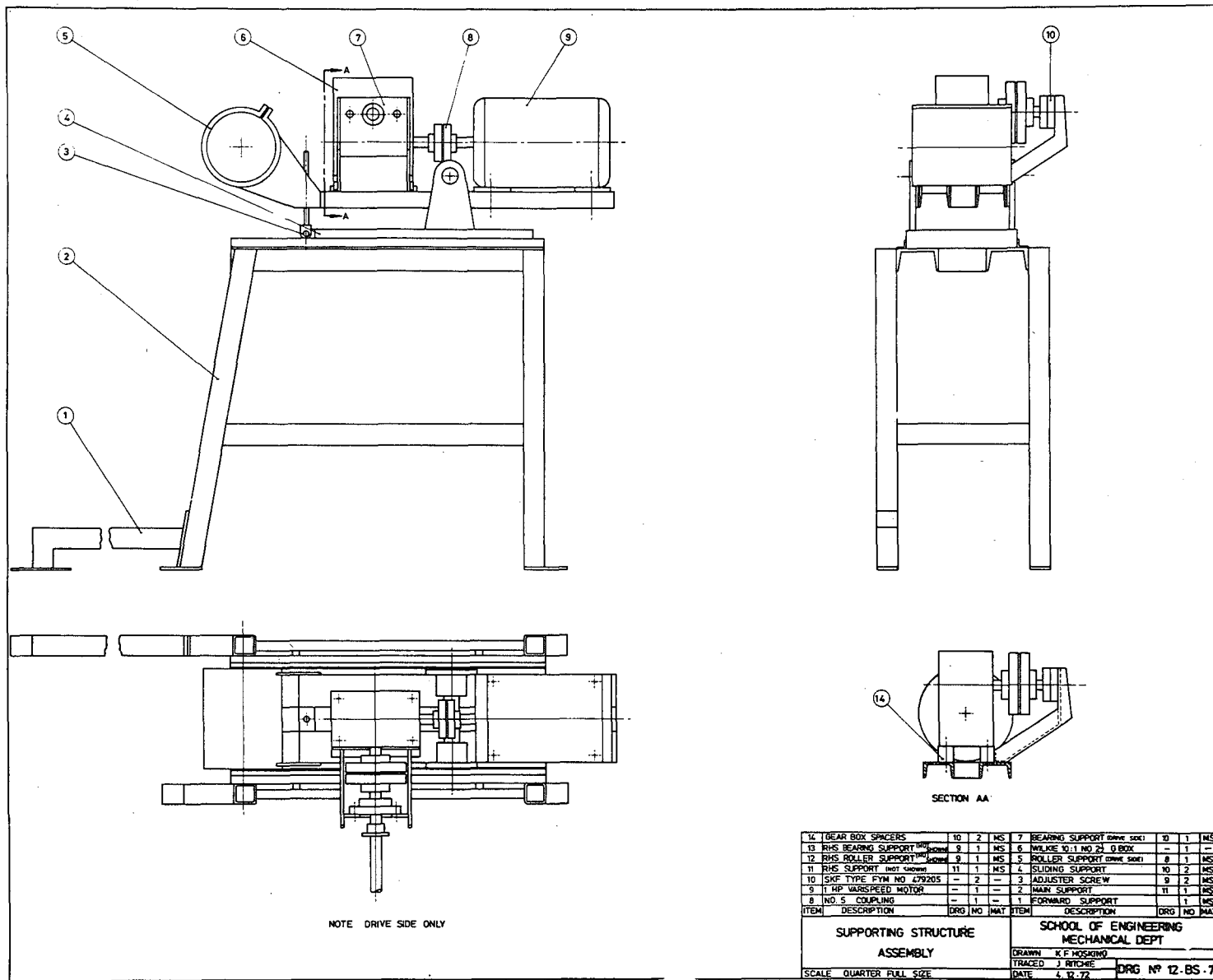


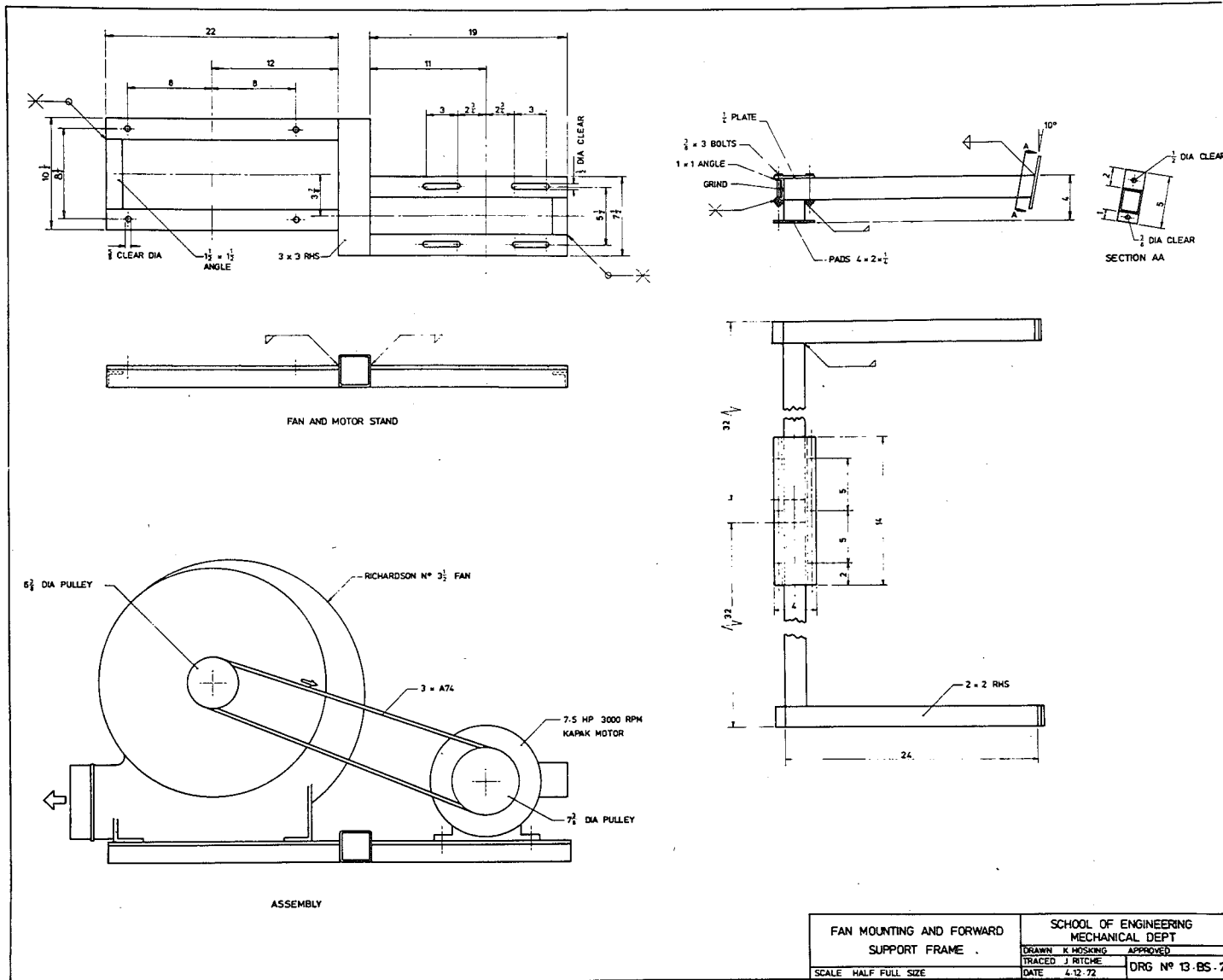
VERTICAL ADJUSTER SUPPORT

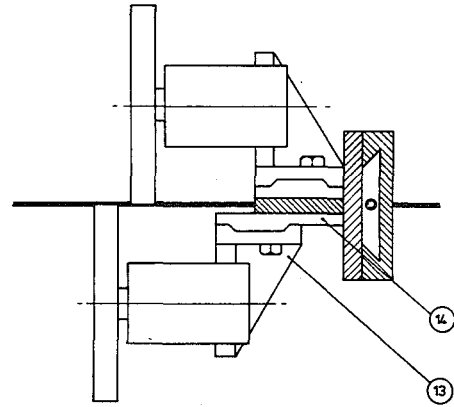
DRIVE BEARING SUPPORT (RHS)
SEE DRG /BS/72 (LHS)

- NOTES
- 1 MACHINE TOP OF PADS TO ALIGN G/BOX & MOTOR
 - 2 ALSO TWO PADS 1/2 DIA DRILLED 1/2 DIA MACHINE AS ABOVE
 - 3 TO FIT SKF 476205-100 SUPPLIED
 - 4 TOLERANCES FRACTIONS $\pm \frac{1}{16}$
 - 5 DECIMALS $\pm .010$
 - 6 DIMENSIONS-INCHES

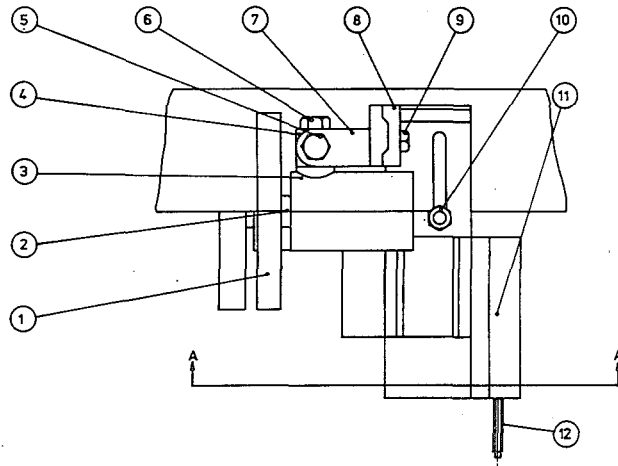
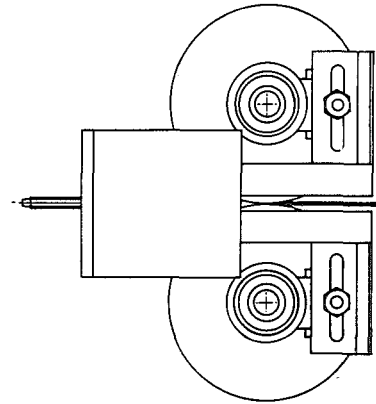
DETAILS HEIGHT		SCHOOL OF ENGINEERING	
ADJUSTER & SUPPORTS		MECHANICAL DEPT	
SCALE HALF FULL SIZE		DRAWN K F HOSKING APPROVED	
		TRACEO J RITCHIE	
		DATE 13.11.72	
		DRG N° 11.BS.72	





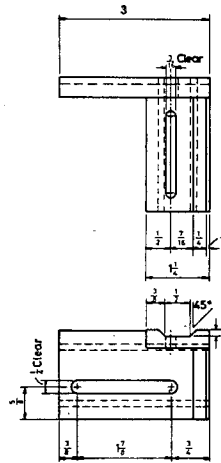


SECTION A-A



14	3	1	Main Slide	M.S.
13	3	1	Slide Track & Slide (Lower)	M.S.
12	3	1	Slide Adjusting Screw	M.S.
11	3	1	Main Slide Body	M.S.
10	-	2	Slide Lock Bolt 1/2 x 1 W.W.	M.S.
9	-	2	Slide Lock Bolt 1/2 x 1 W.W.	M.S.
8	2	1	Slide Track & Vert. Slide	M.S.
7	2	2	Clevis & Slide Assembly	M.S.
6	-	2	Pivot Block Lock Bolt	M.S.
5	2	2	Clevis Lock Bolt	M.S.
4	2	2	Pivot Block	M.S.
3	2	2	Bearing Housing (For SKF 6201)	M.S.
2	2	2	Shaft	M.S.
1	-	2	Grinding Wheels	-

GRINDING APPARATUS ASSEMBLY		SCHOOL OF ENGINEERING MECHANICAL DEPT.	
DRAWN - K.F. HOSKING		APPROVED -	
TRACED - V.J. GREY		DRG. No. 1-BS-73	
SCALE - FULL SIZE		DATE - 21-3-73	

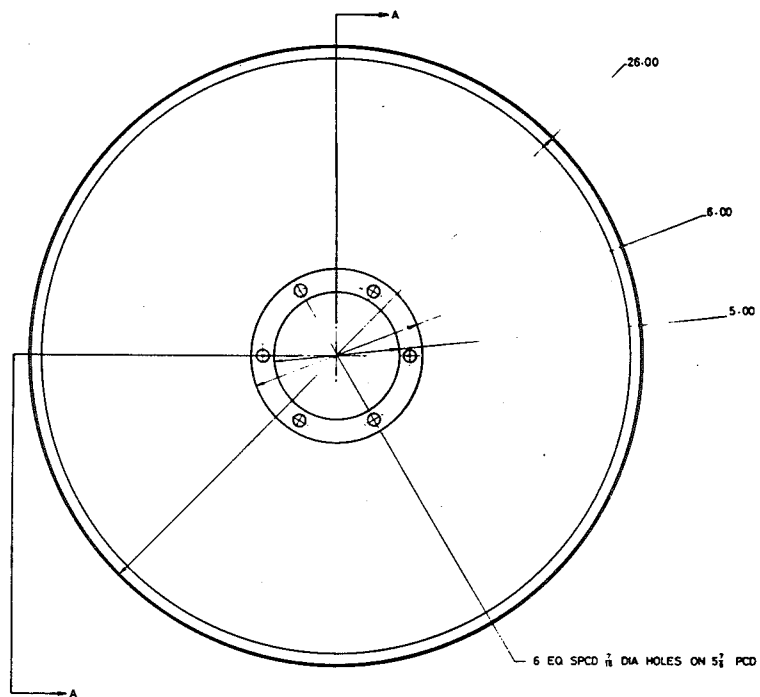
[illegible]

Technical drawing of a mechanical part with the following dimensions and features:

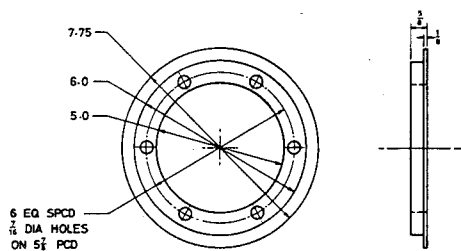
- Overall height: 3
- Overall width: 2
- Top horizontal segment: 1
- Vertical segment from top: 1
- Horizontal segment from vertical: 1
- Bottom horizontal segment: 1
- Vertical segment from bottom: 1
- Horizontal segment from vertical: 1
- 45° angle indicated on the right side.
- Label: Exp. 4. WW.

TOLERANCES :- FRACTIONS $\pm \frac{1}{16}$
DECIMALS ± 0.010
UNLESS IND.
ALL DIMENSIONS IN INCHES.

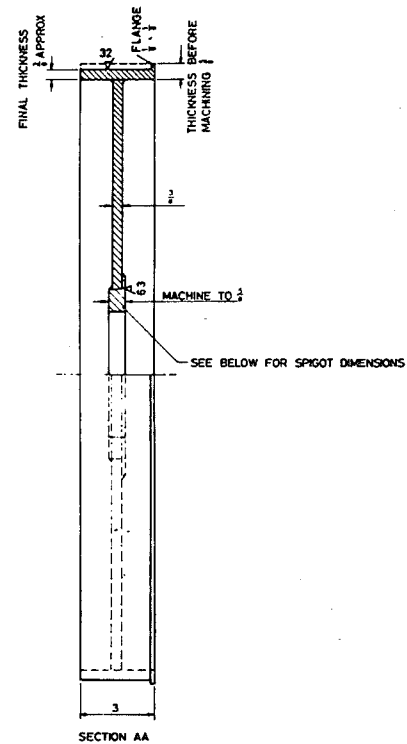
213.



WHEEL ASSEMBLY (2)



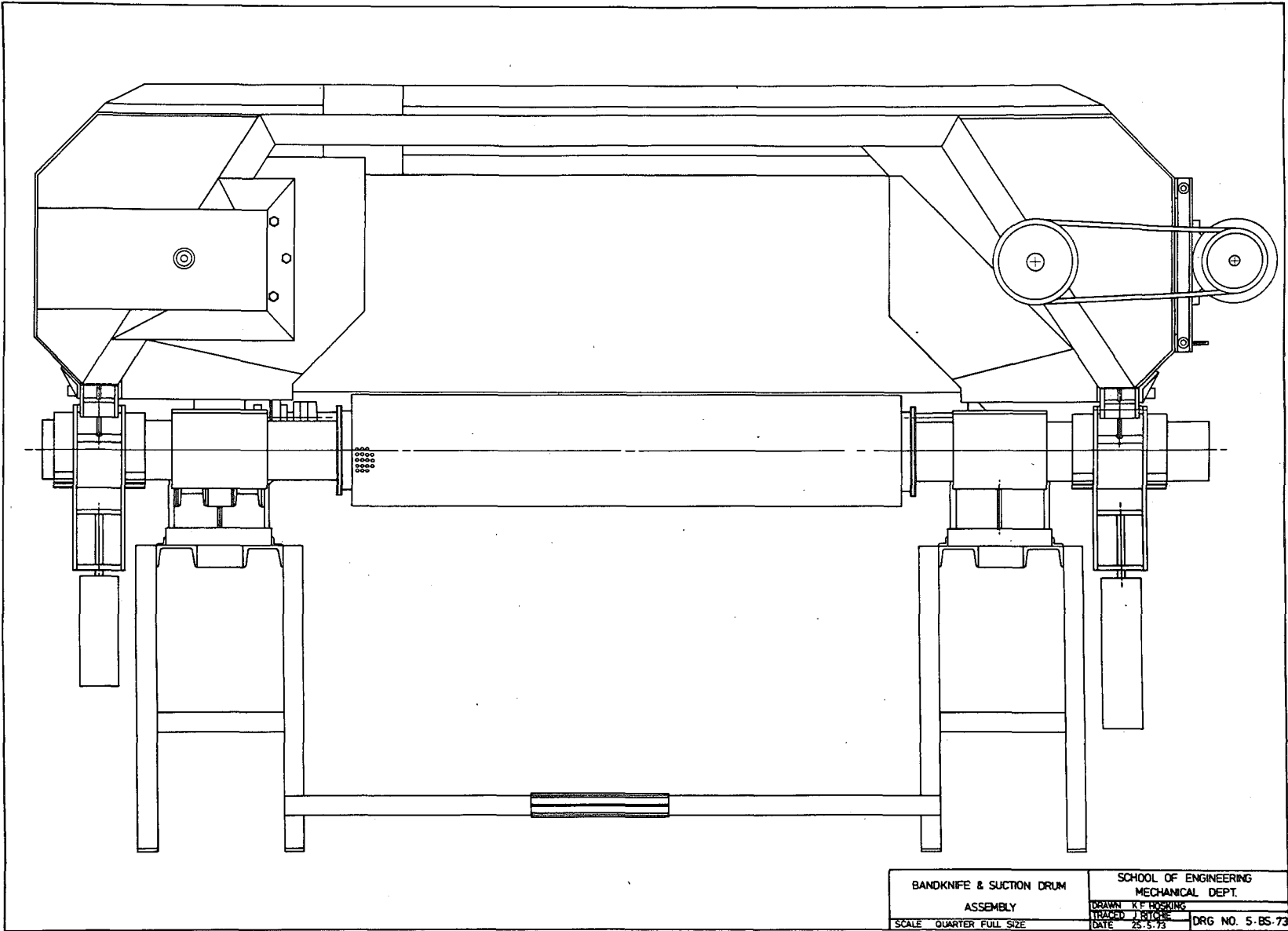
CENTRAL SPIGOT (2)

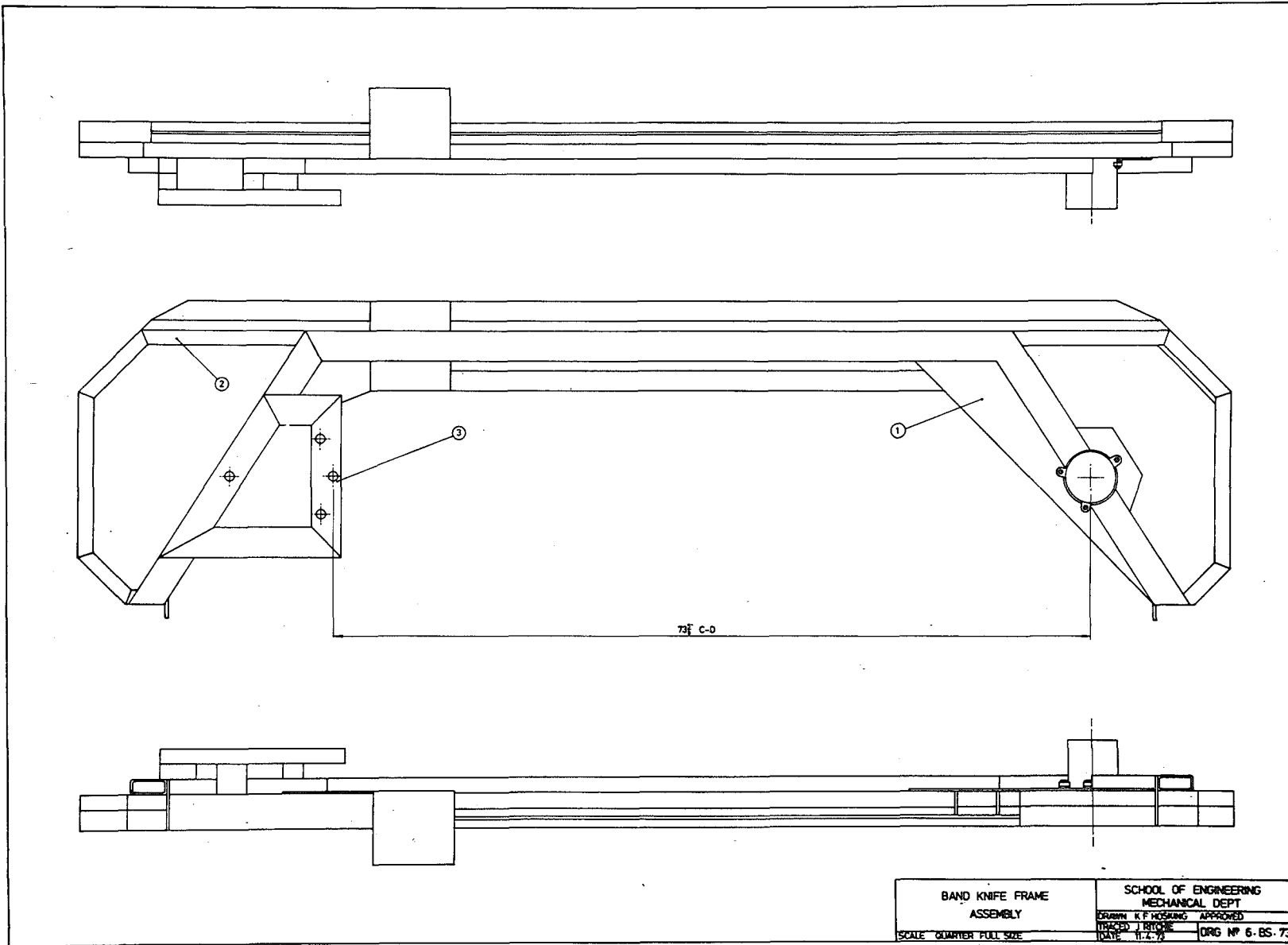


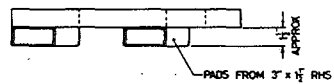
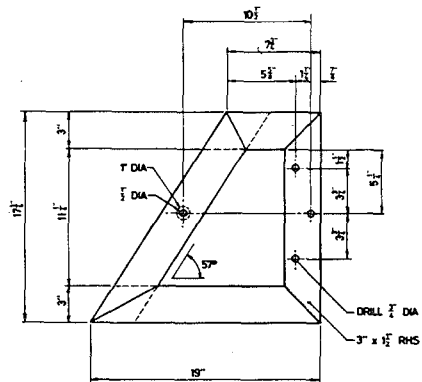
NOTES

- 1 RIM TO BE ROLLED BY OUTSIDE INDUSTRY BUTT WELD
- 2 CENTRE DISC TO BE DOUBLE FILLET WELDED TO RIM SIMILARLY TO CENTRAL SPIGOT.
- 3 MACHINE DOWN TO 26.0 DIAMETER AND BORE CENTRE TO 5" DIAMETER.
- 4 SPIGOT FACES TO BE MACHINED TO FACE ONTO CENTRAL BOSS SUPPLIED.
- 5 COMPLETED WHEELS TO BE BALANCED AND TRUED
- 6 DIMENSIONS IN INCHES.

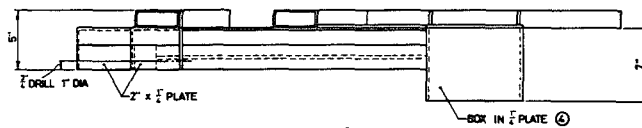
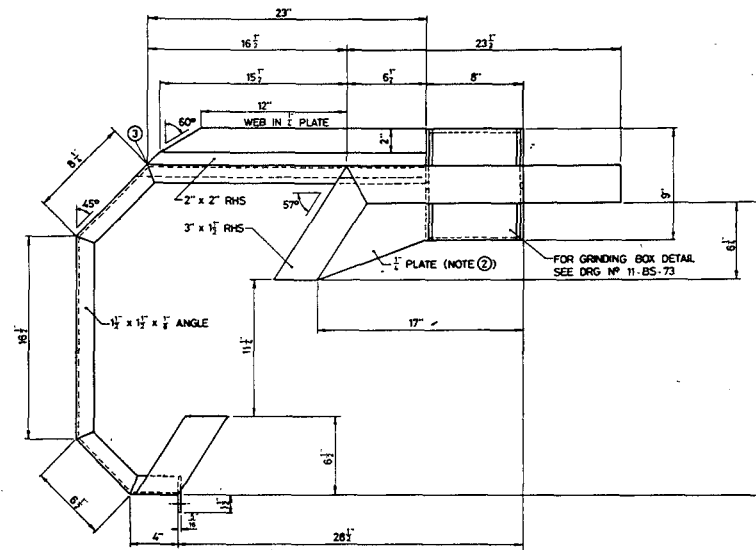
MATERIAL M.S.	
SCHOOL OF ENGINEERING	
MECHANICAL DEPT	
DRAWN K.F. HOSKING APPROVED	
TRACED J. RITCHIE	
SCALE HALF FULL SIZE	DATE 2.2.73 DRG N° 4-BS-73







SUB-ASSEMBLY ③

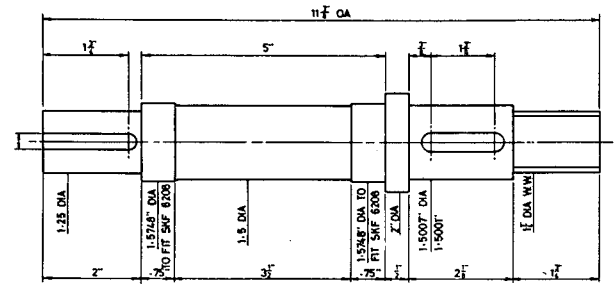


SUB ASSEMBLY ②

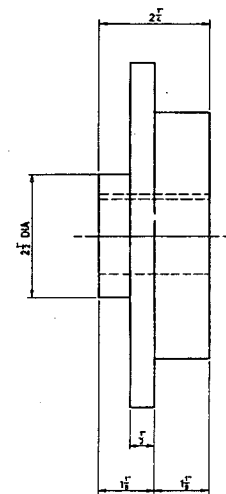
- NOTES
- 1 WELD SUB ASSEMBLY ① TO ②
 - 2 GUSSET PLATE FORMS BACK OF GRINDING BOX
 - 3 2" x 2" RHS MERGES WITH 1/2" x 2" PLATE AT ③
 - 4 DIAGONAL MEASUREMENTS APPROX ONLY
 - 5 TOLERANCES: DECIMALS = .010 FRACTIONS = 1/16

BANDKNIFE FRAME (DETAILS)	SCHOOL OF ENGINEERING MECHANICAL DEPT
SCALE QUARTER FULL SIZE	APPROVED TRACED J. RITCHIE DATE 11.4.73 DRG NO 7-BS-73

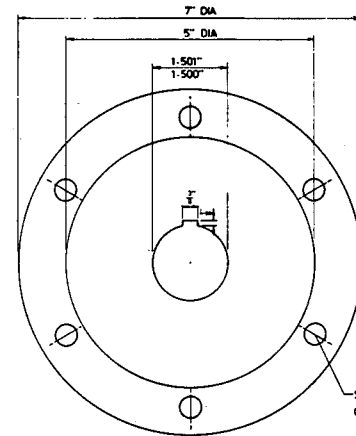




DRIVE SHAFT

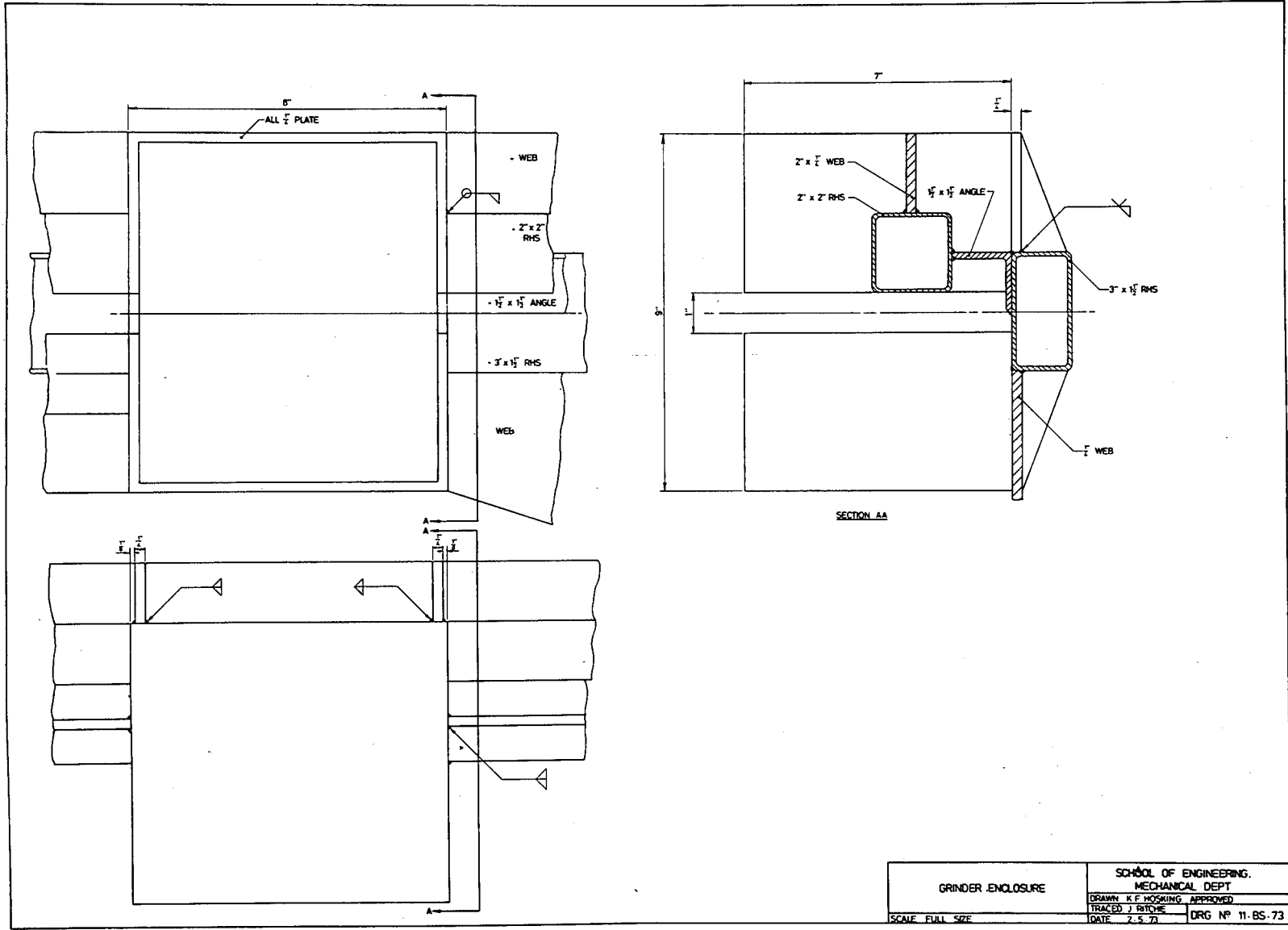


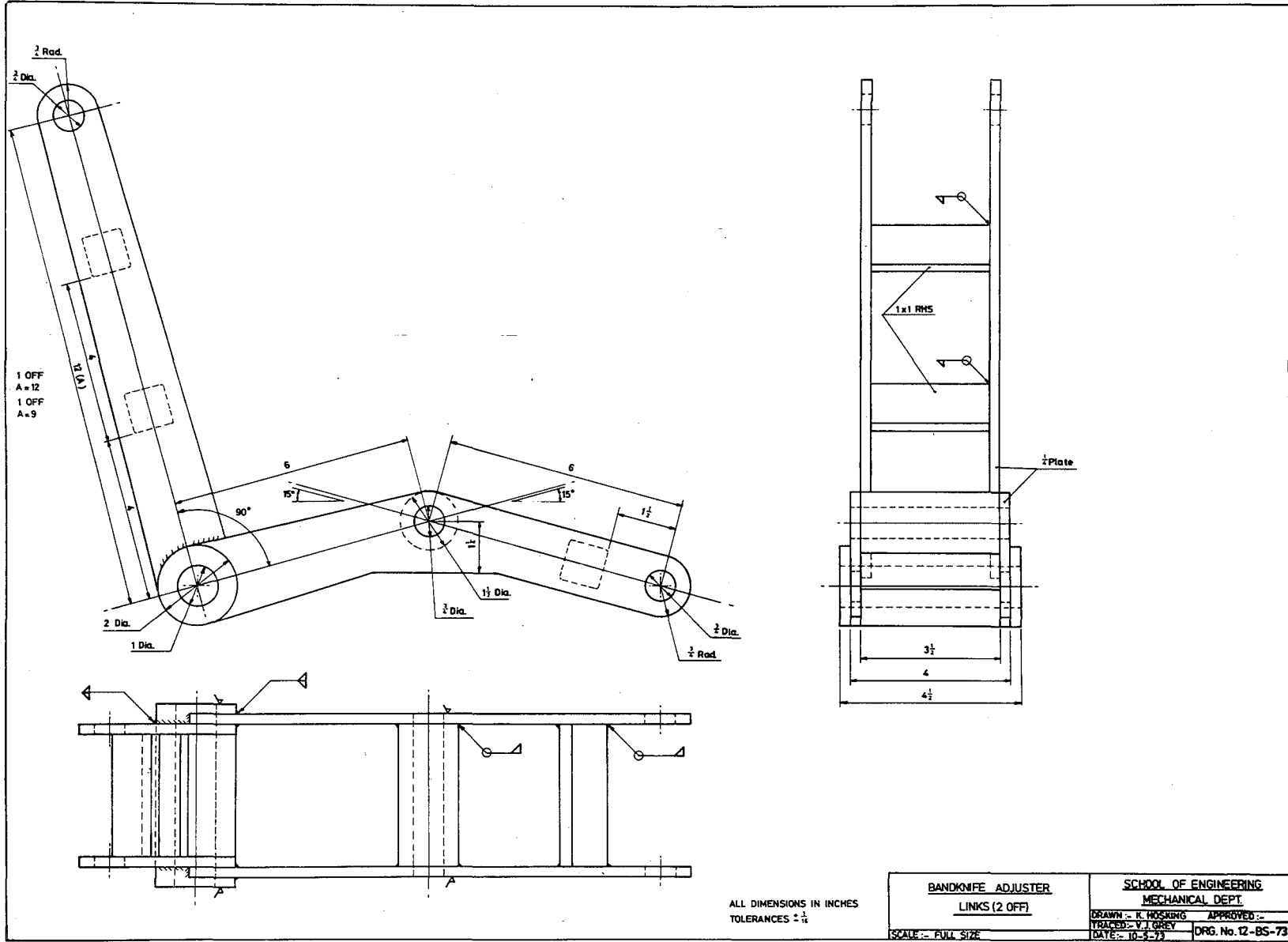
FLANGE

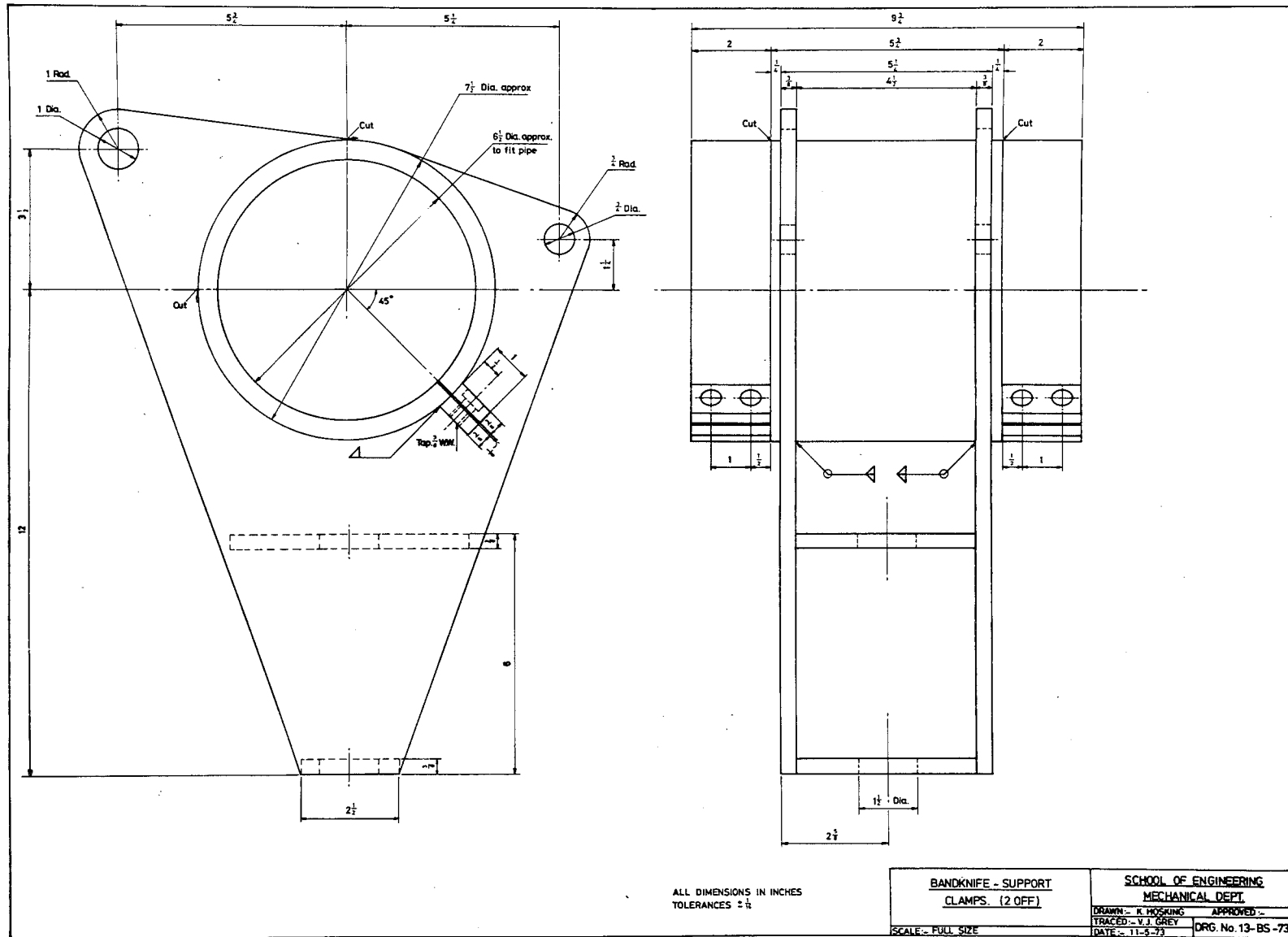


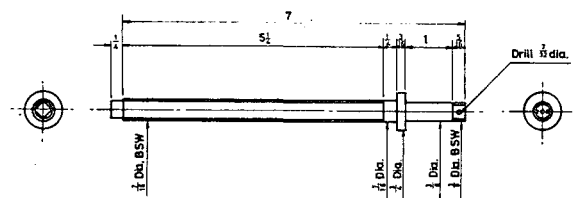
SIX $\frac{1}{8}$ " DIA CLEAR HOLES
ON $\frac{5}{16}$ " PCD EQ SPCD

BANDKNIFE DETAILS	SCHOOL OF ENGINEERING MECHANICAL DEPT	
	DRAWN: K. HOSKING	APPROVED:
SCALE: FULL SIZE	TRACED: J. RICHIE	DATE: 10.4.73
		DRG NO: 9.BS.73

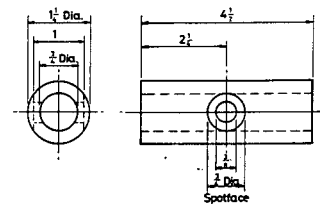




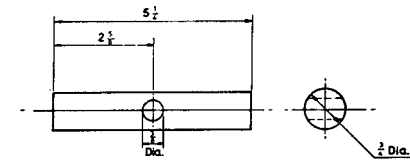




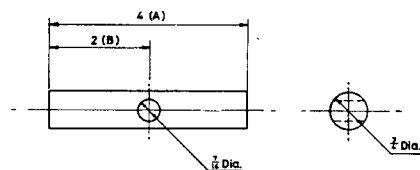
③ ADJUSTING SCREW (4)



④ SLEEVE (4)

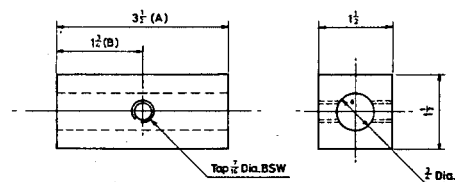


⑤ PIN (4)



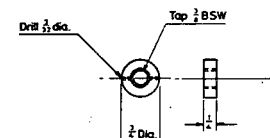
② UPPER PIN (2)

Also (2) with $A = 3\frac{1}{2}$, $B = 1\frac{1}{2}$

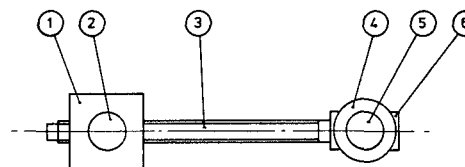


① ADJUSTING BLOCK (2)

Also (2) with $A = 3$, $B = 1\frac{1}{2}$



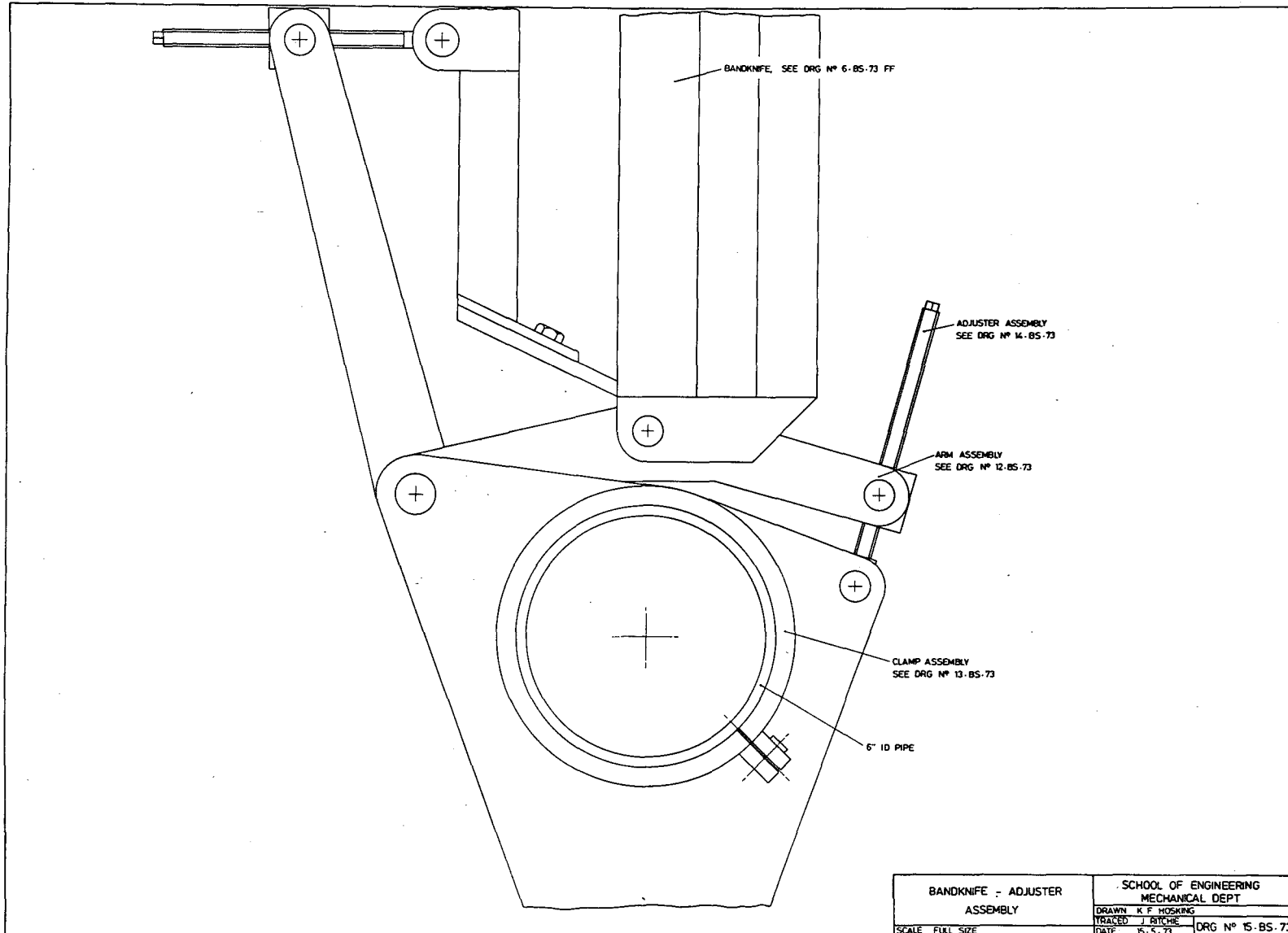
⑥ COLLAR (4)

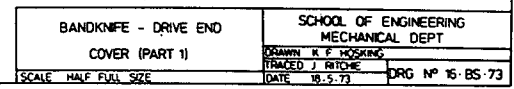


ASSEMBLY

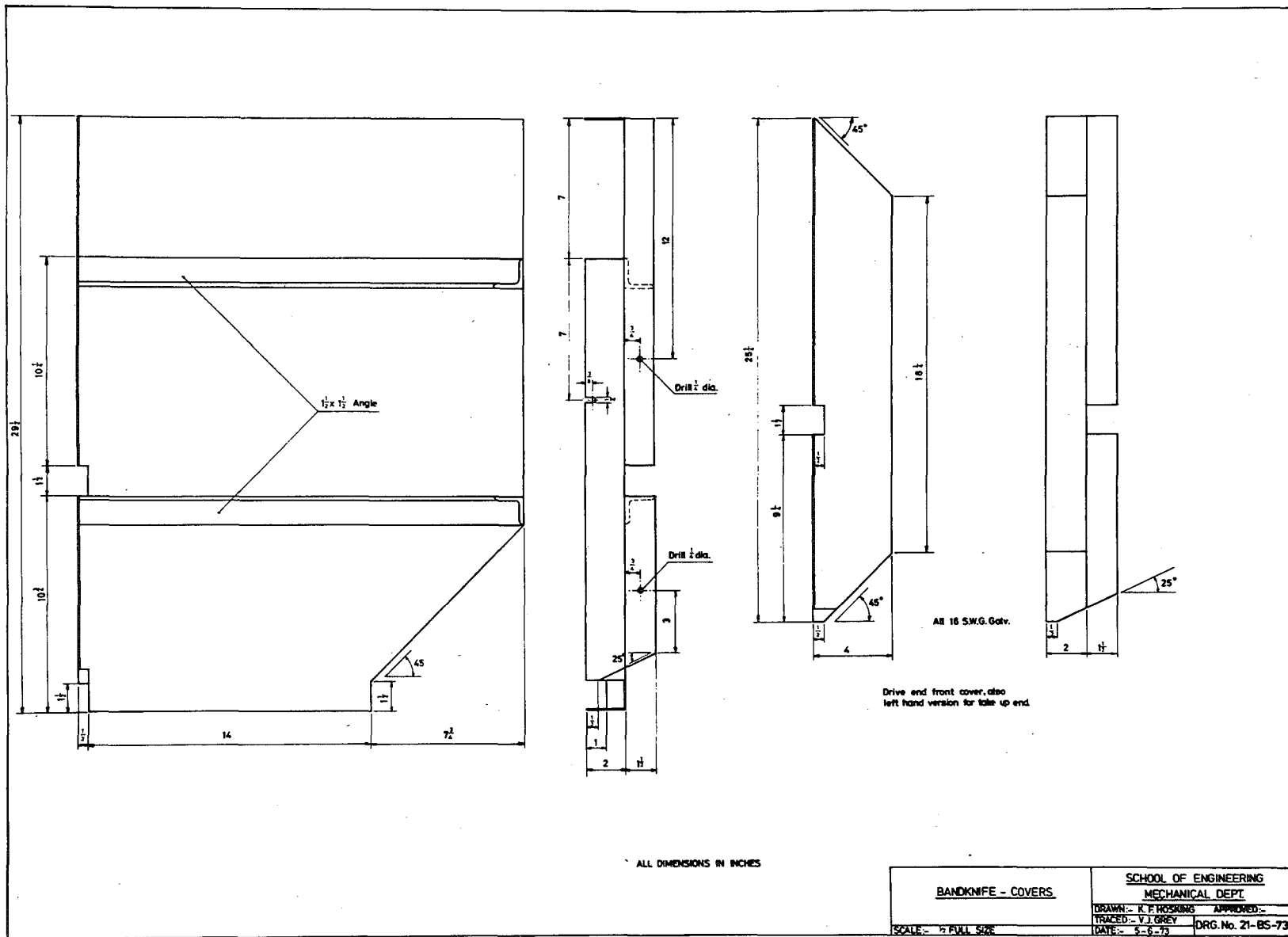
ALL DIMENSIONS IN INCHES

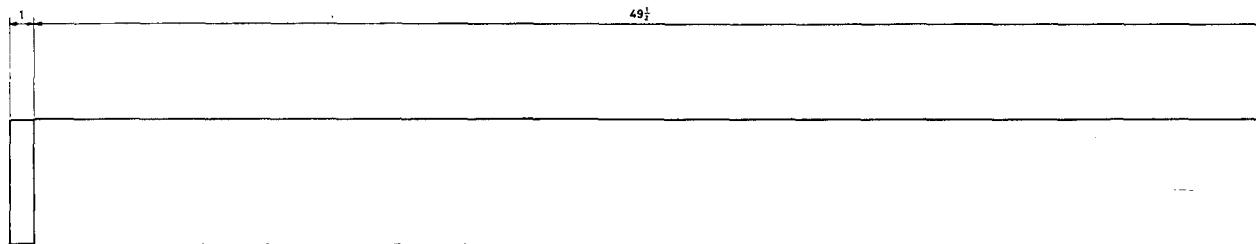
BANDKNIFE ADJUSTER DETAILS	SCHOOL OF ENGINEERING MECHANICAL DEPT.
SCALE - FULL SIZE	DRAWN - K. F. HOSKING TRACED - V. J. GREY DATE - 14-5-73 APPROVED - DRG. No 14-BS-73



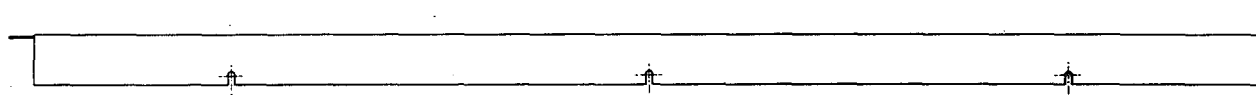
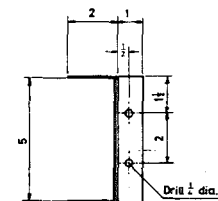






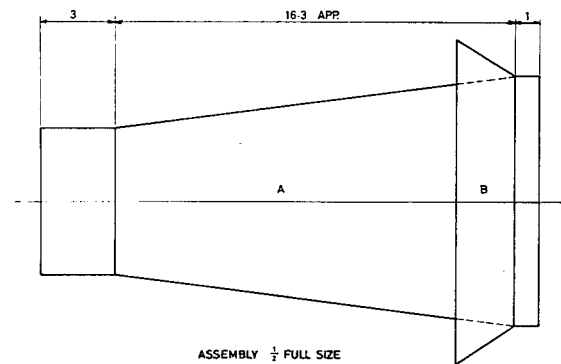


Bend down one layer (16 S.W.G.)

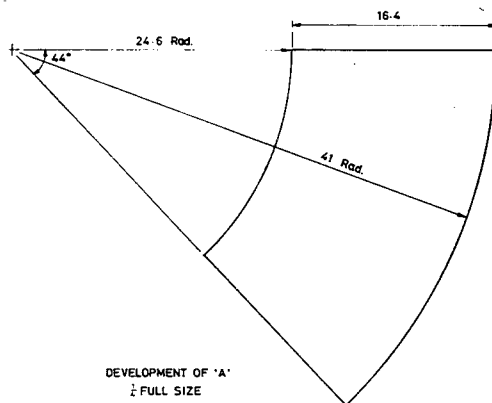
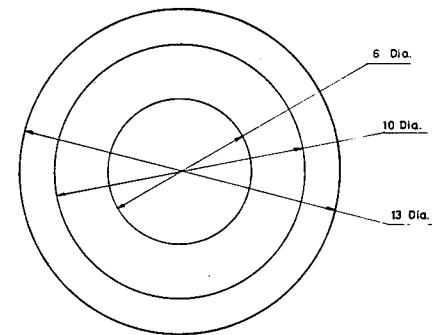


ALL DIMENSIONS IN INCHES

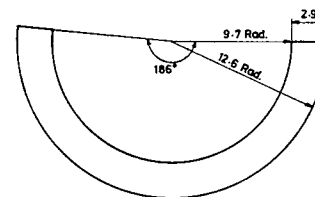
BANDKNIFE - COVERS		SCHOOL OF ENGINEERING	
		MECHANICAL DEPT.	
DRAWN - R. HOSKINS	APPROVED -		
TRACED - V. J. GREY			
SCALE - 1/2 FULL SIZE	DATE - 12-6-73	DRG. No. 23-B5-73	



ASSEMBLY $\frac{1}{2}$ FULL SIZE



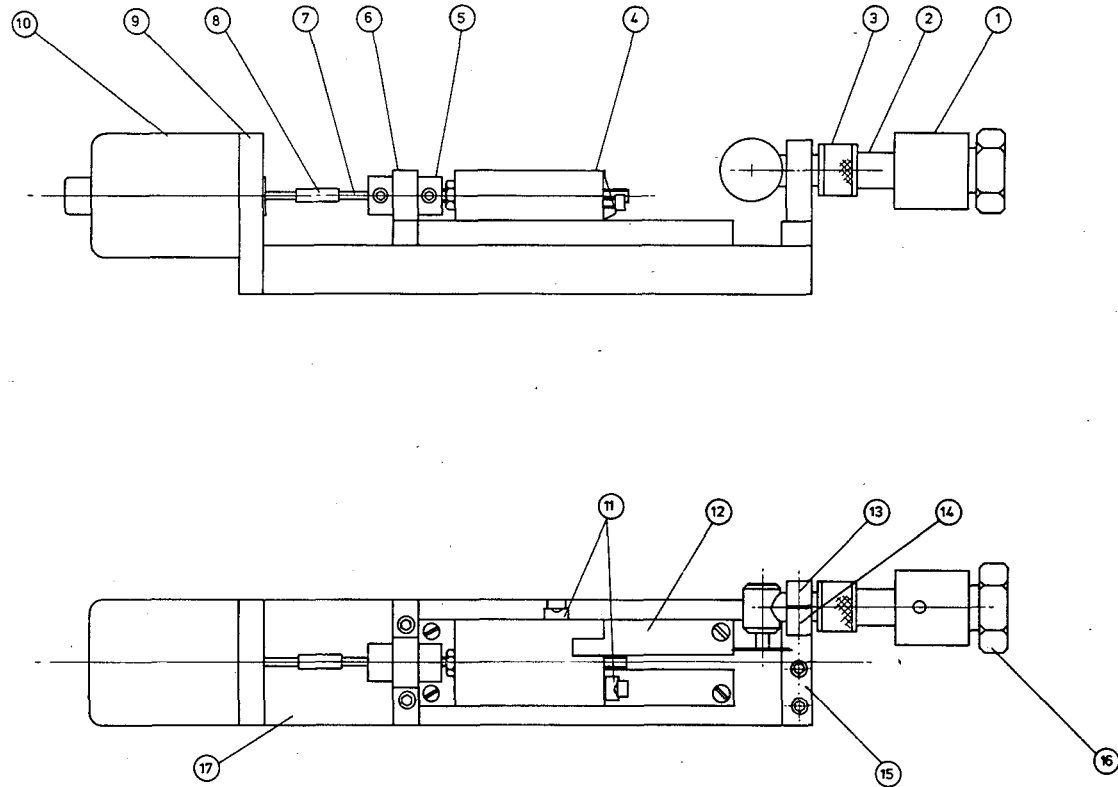
DEVELOPMENT OF 'A'
 $\frac{1}{2}$ FULL SIZE



DEVELOPMENT OF 'B'
 $\frac{1}{2}$ FULL SIZE

MATERIAL: 18 SW.G. GALV.
ALL DIMENSIONS IN INCHES.

DIFFUSER	SCHOOL OF ENGINEERING	
	MECHANICAL DEPT	
	DRAWN - K HOSKING	APPROVED -
	TRACED - V J GREY	DATE - 19-12-73
SCALE - AS INDICATED		DRG No 24-B5-73



18	1	See Piece (not shown)	M.S.
17	1	Main Base Plate	Al.
16	1	Union (std fitting)	Brass
15	1	Support Base	Al.
14	1	Clamp	Al.
13	1	Clamp Support	Al.
12	2	Slide Rails	M.S.
11	2	Clap	Steel
10	1	Motor	-
9	1	Face Plate	Al.
8	1	Rubber Joint	Rubber
7	1	Sheet	M.S.
6	1	Thrust Saddle	Al.
5	2	Collar	Brass
4	1	Slide	Al.
3	1	Sleeve Nut	Brass
2	1	Airline Plug	Brass
1	1	Adapter Plug	Brass
ITEM NO.			DESCRIPTION
			MAT.

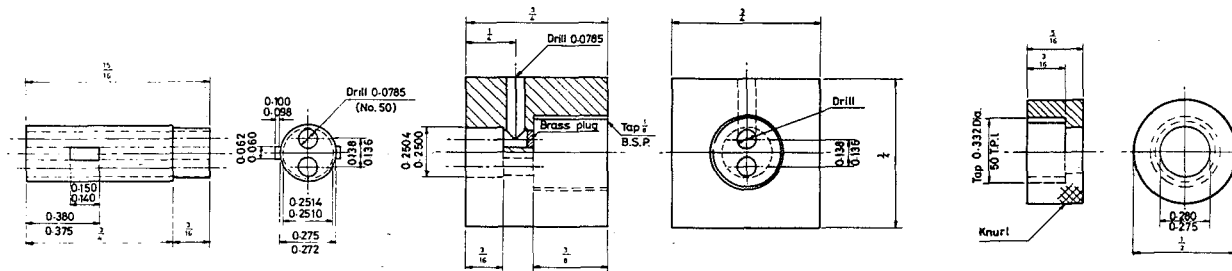
**MICROCUTTER
ASSEMBLY**

SCALE - 2x FULL SIZE

**SCHOOL OF ENGINEERING
MECHANICAL DEPT.**

DRAWN - R.F. HOSKING APPROVED -
TRACED - V.J. GREY
DATE - 31-7-73

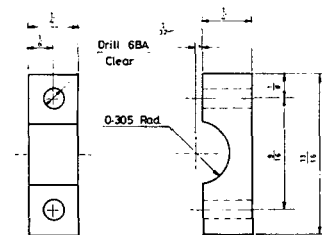
DRG No 1-BS-74



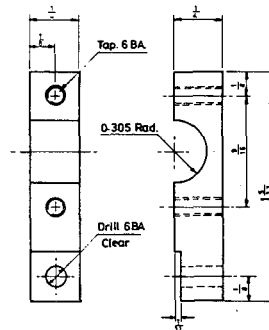
2 AIRLINE PLUG

1 ADAPTOR BUSH

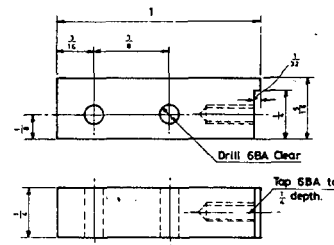
3 SLEEVE NUT



14 CLAMP



13 CLAMP SUPPORT

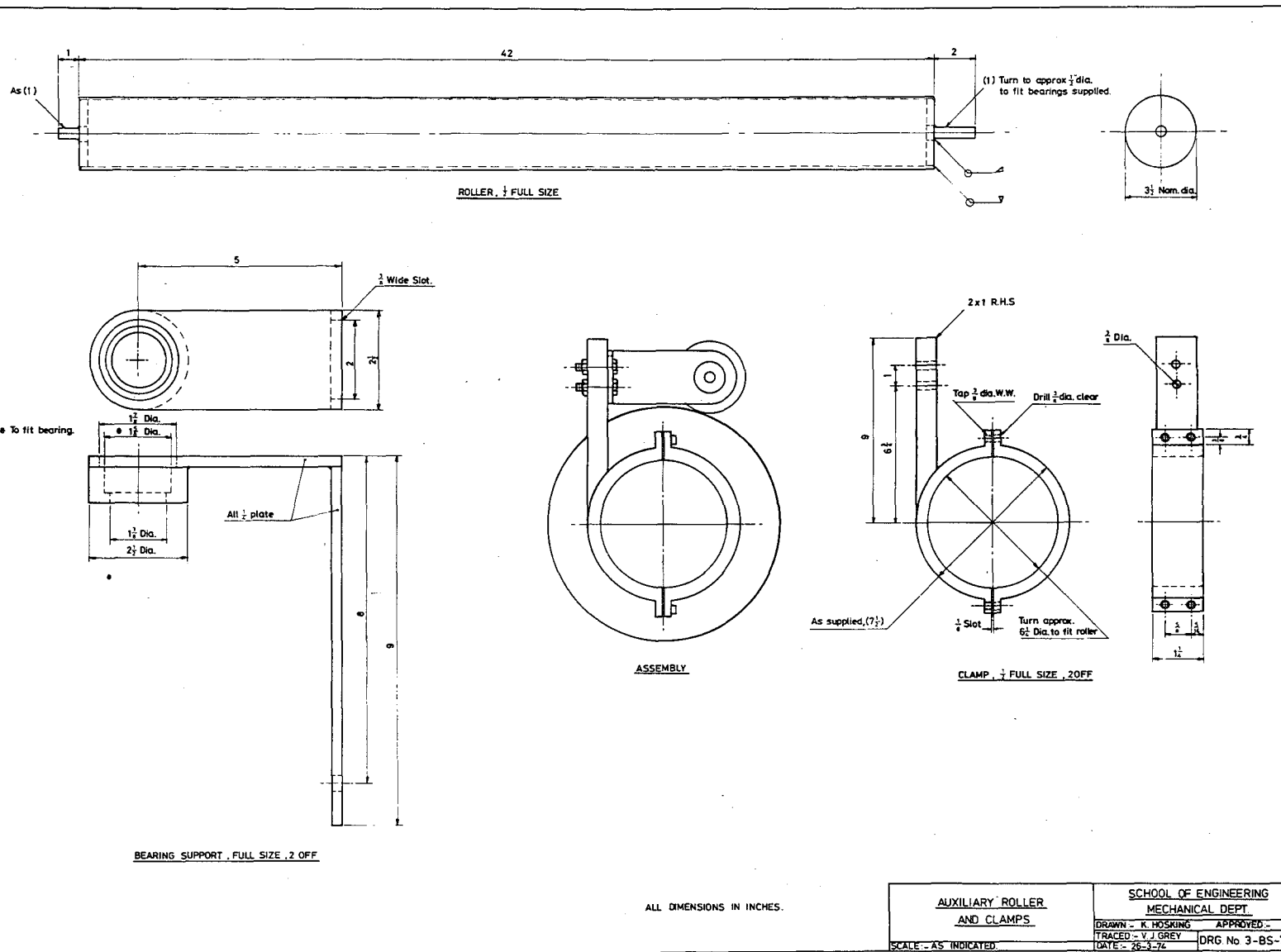


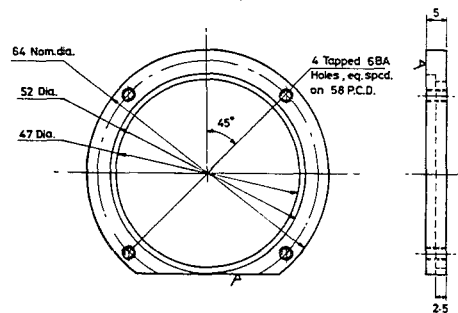
15 SUPPORT BASE

ALL DIMENSIONS IN INCHES
TOLERANCES: (UNLESS INDICATED)
- DECIMALS ± 0.010
- FRACTIONS ± 1/16

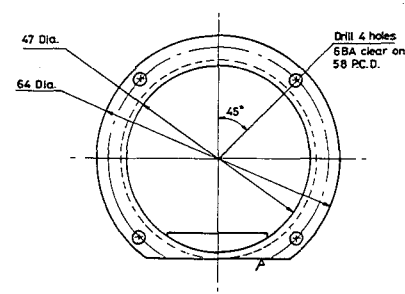
FOR PARTS LIST SEE 1-B5-74

MICROCUTTER DETAILS		SCHOOL OF ENGINEERING MECHANICAL DEPT.	
DRAWN - K. HOSKING		APPROVED -	
TRACED - V. J. GREY		DRG No. 2-B5-74	
SCALE - 4 x FULL SIZE		DATE - 18-7-73	

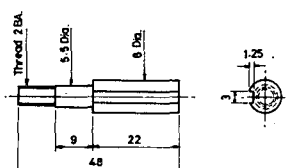
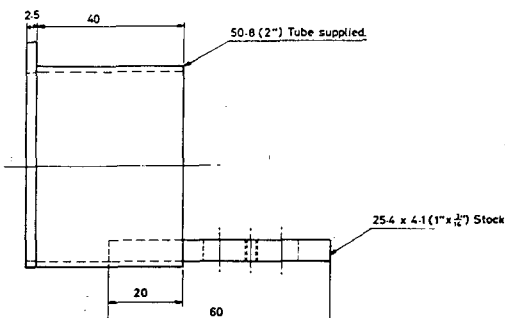




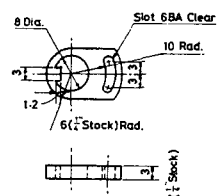
1 FRONT FLANGE



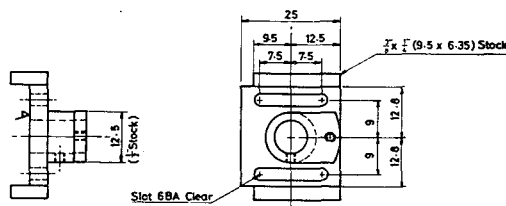
2 REAR FLANGE AND BODY



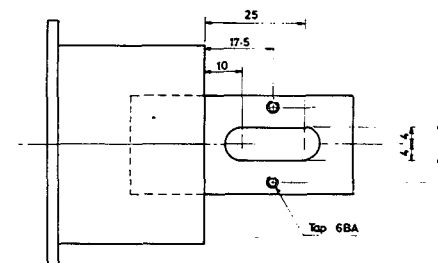
3 SHAFT



4 CLAMP



5 SLIDE



ALL DIMENSIONS IN MILLIMETRES
3RD ANGLE PROJECTION
TOLERANCE ± 0.05

HALOGEN LAMP
HOLDER

SCALE - TWICE FULL SIZE

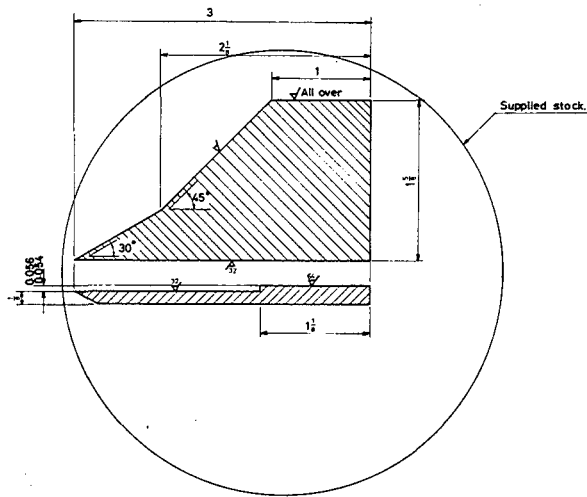
ITEM	DESCRIPTION	REQUIREMENT
5	Sliding Plate and Boss	1 Brass
4	Clamp for Shaft	1 Brass
3	Support Shaft	1 Brass
2	Rear Flange & Main Body	1 Brass
1	Front Lamp Holding Flange	1 Brass

SCHOOL OF ENGINEERING

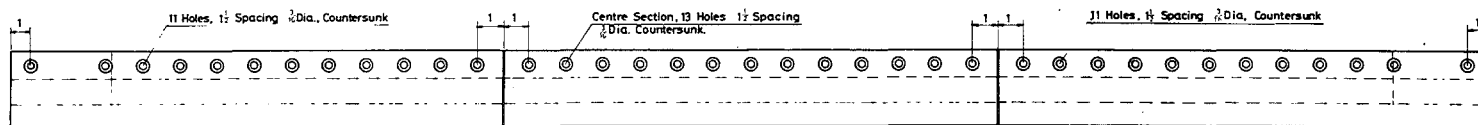
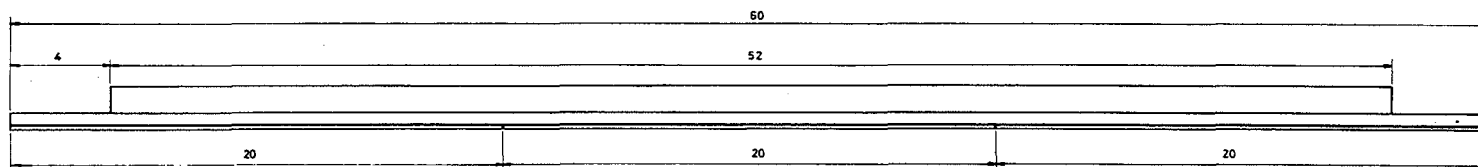
MECHANICAL DEPT

DRAWN - K. N. SINGH APPROVED -

TRACED - V. J. GREY DATE - 17-6-74 DRG No 4-BS-74



BANDKNIFE GUIDE CROSS SECTION $4\frac{1}{2}$ DIA. C.I. STOCK
TWICE FULL SIZE.

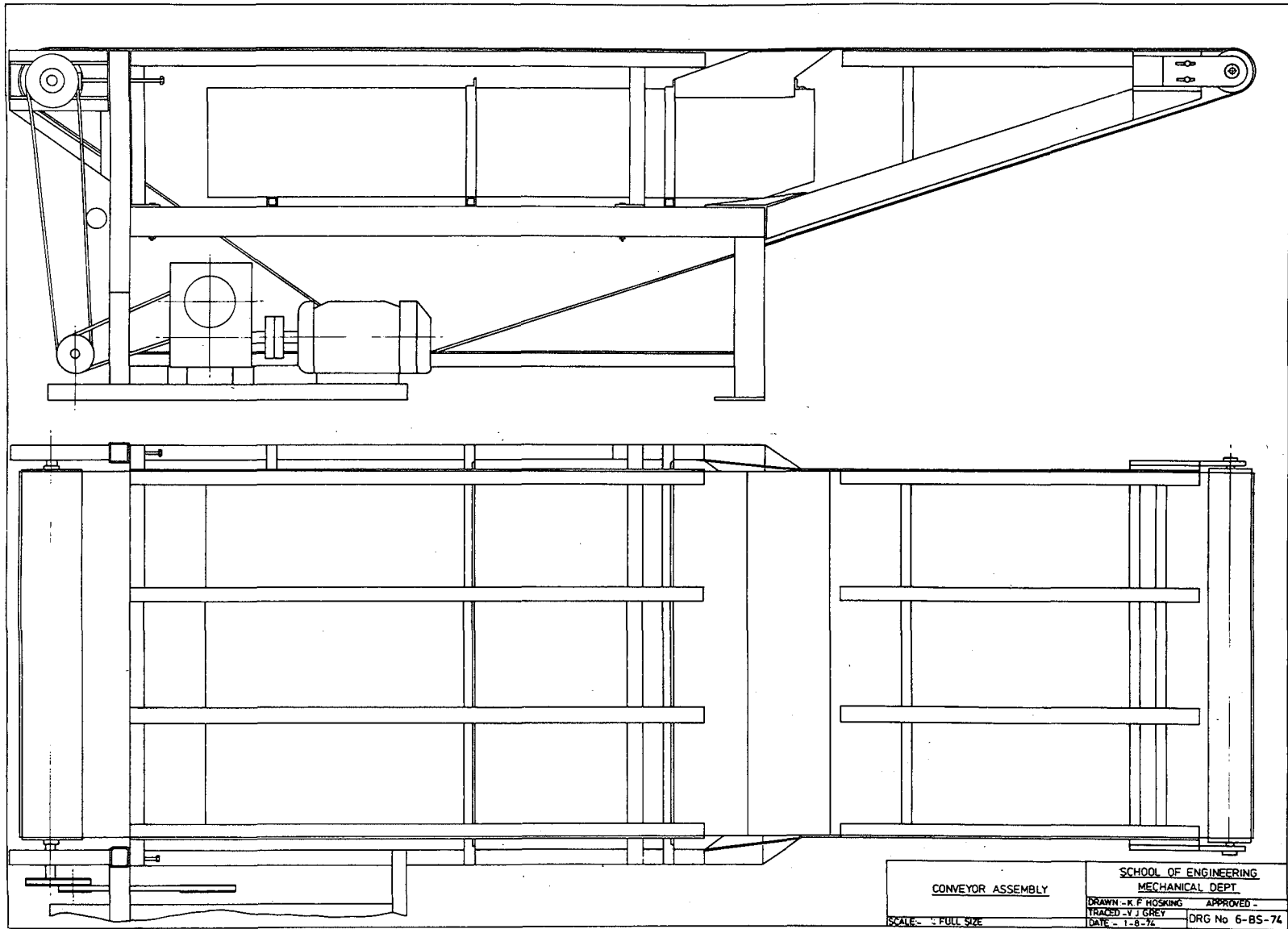


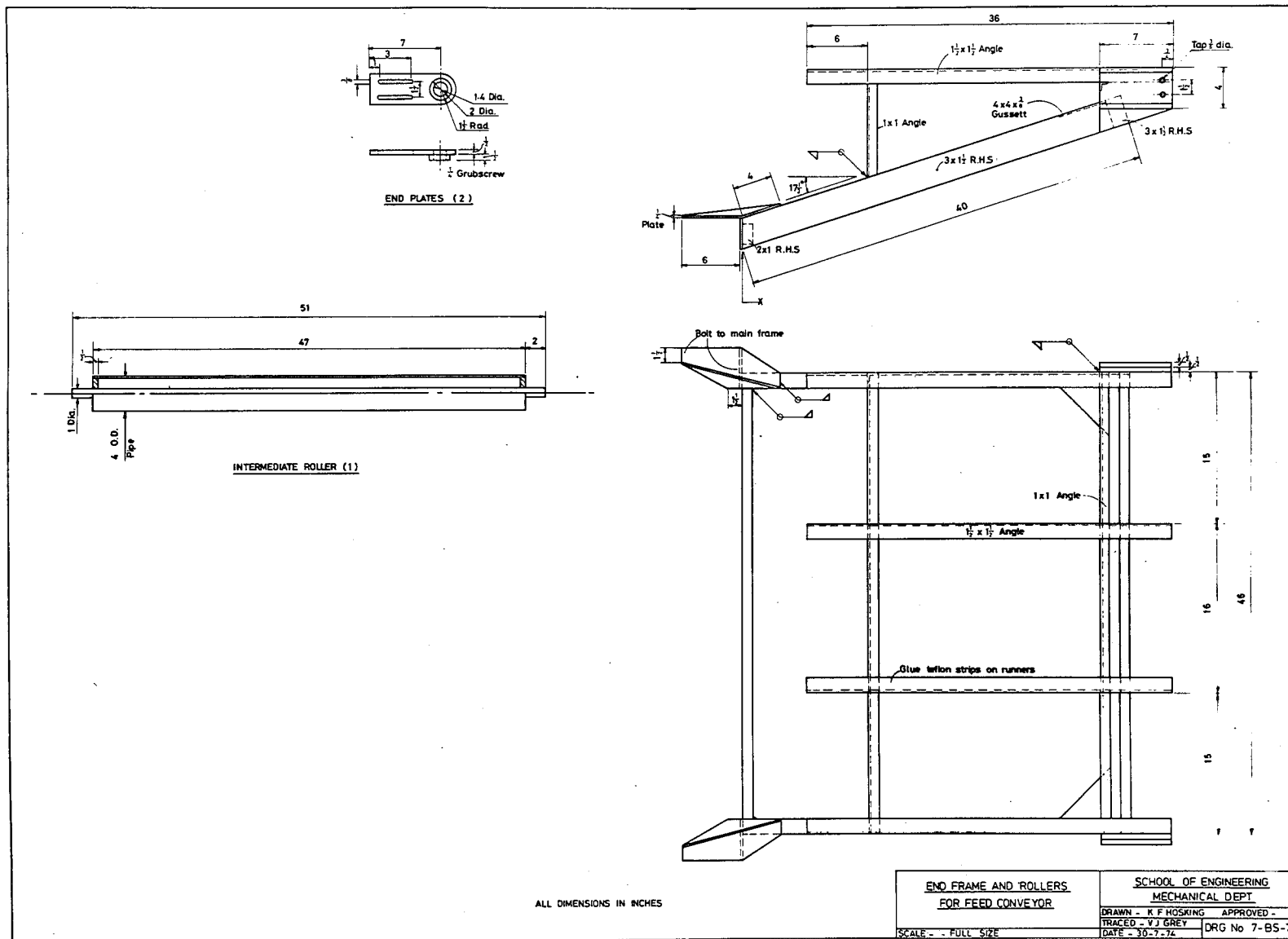
HOLE DETAILS REF. TO LOWER RUN
DRILL AND TAP $\frac{1}{16} \times \frac{1}{2}$ IN UPPER RUN

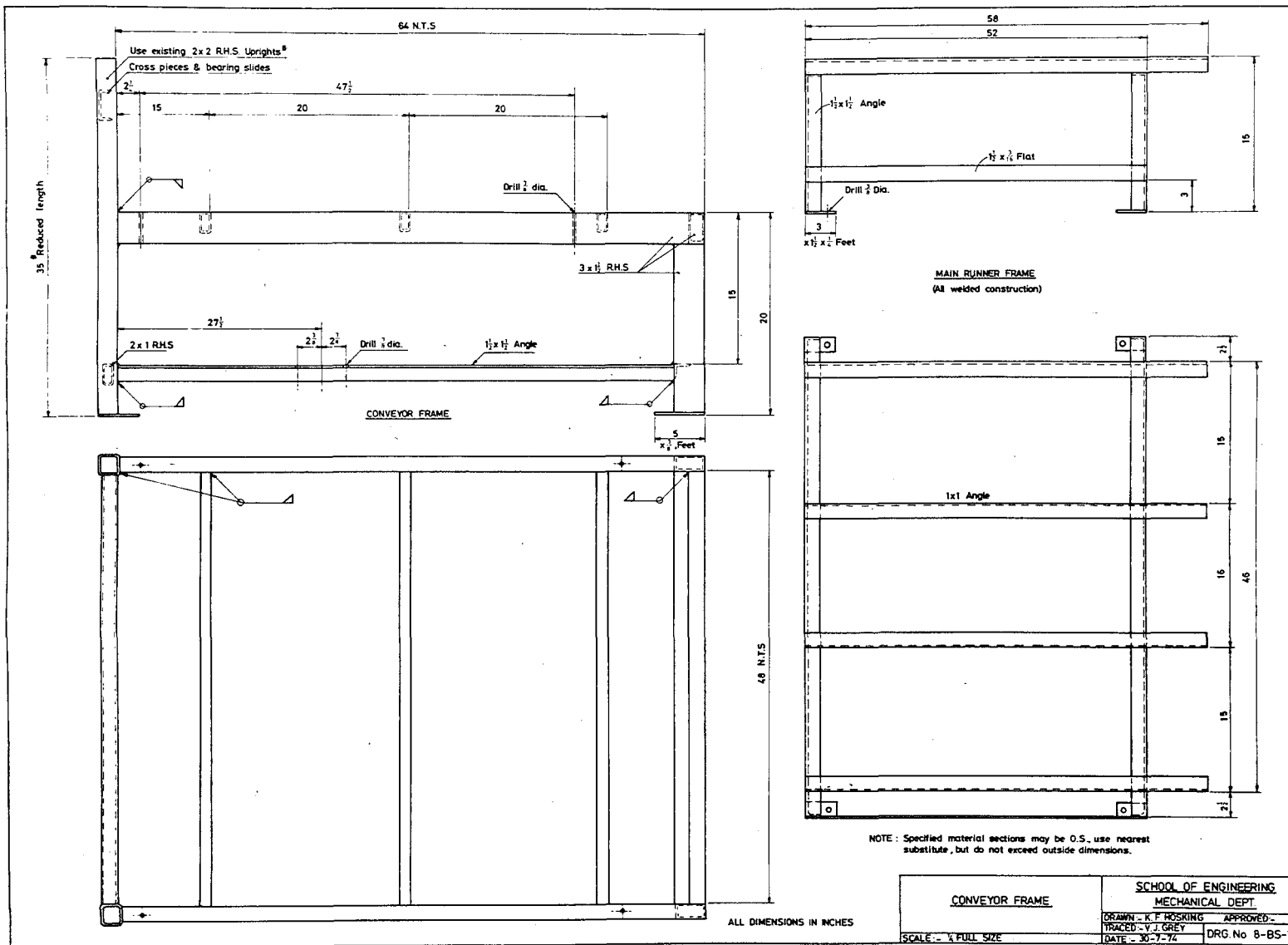
BANDKNIFE GUIDE
 $\frac{1}{2}$ FULL SIZE

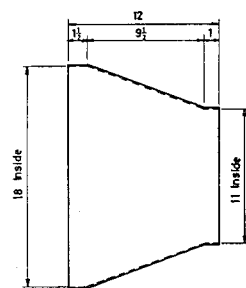
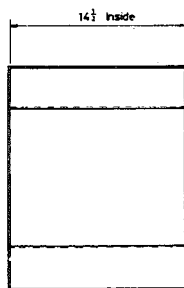
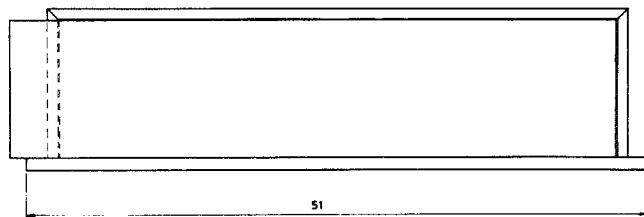
ALL DIMENSIONS IN INCHES

BANDKNIFE GUIDE		SCHOOL OF ENGINEERING MECHANICAL DEPT.	
DRAWN - K. HOSKING		APPROVED -	
TRACED - V. J. GREY		DATE - 17-5-74	
SCALE - AS INDICATED		DRG. No. 5-BS-74	

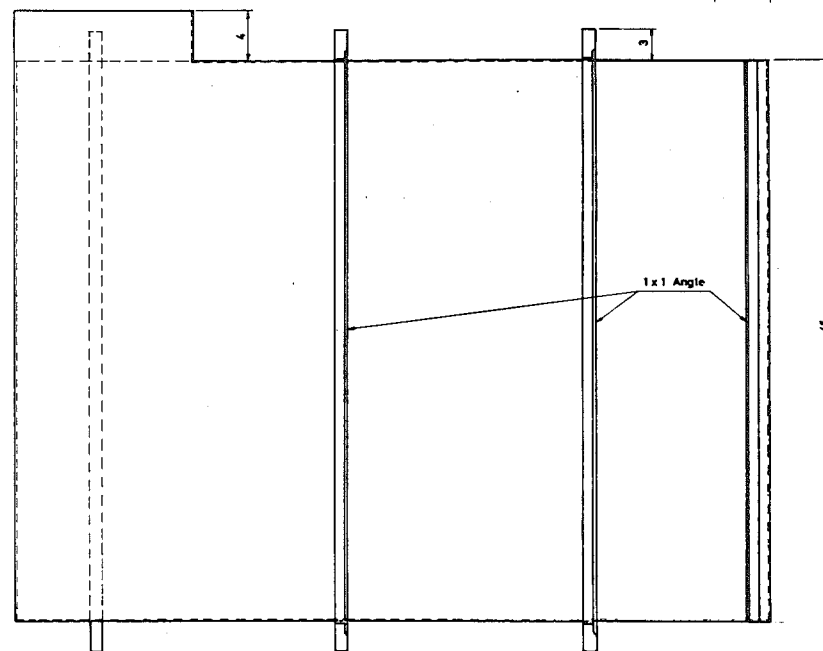
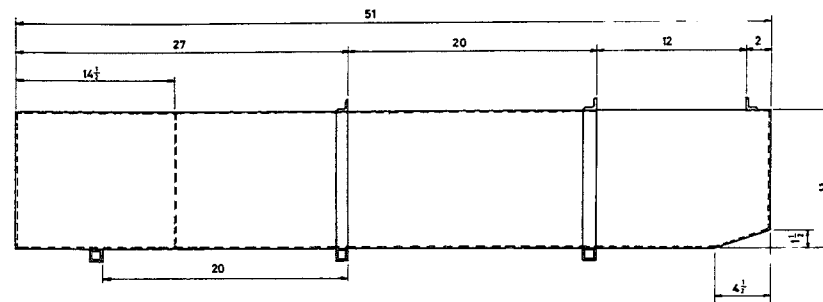








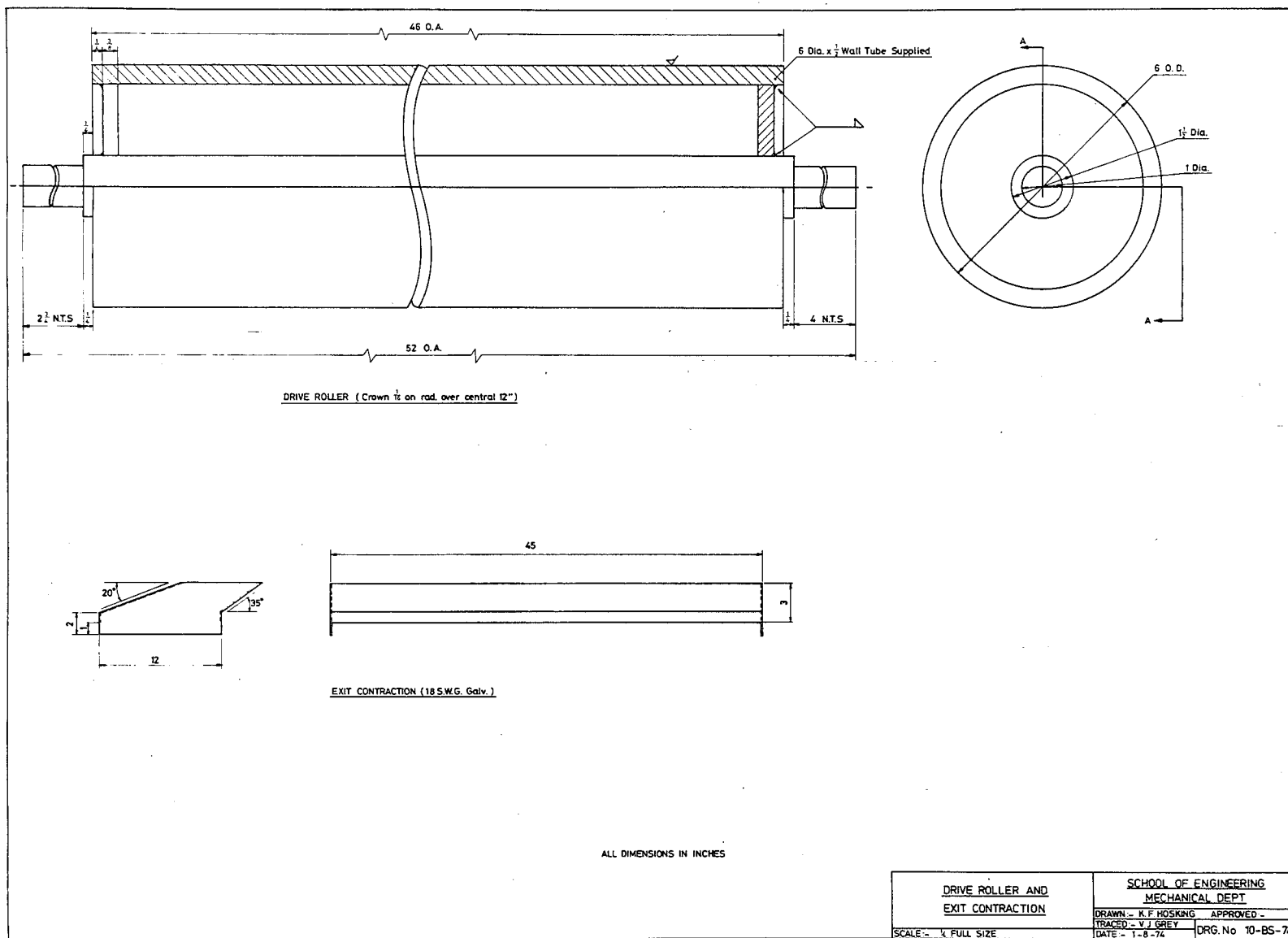
CONTRACTION (All 18 SWG. Galv.)



PLENUM CHAMBER (18 SWG. Galv. Pop rivet to steel section)

ALL DIMENSIONS IN INCHES

PLENUM CHAMBER & CONTRACTION		SCHOOL OF ENGINEERING MECHANICAL DEPT.	
SCALE - FULL SIZE		DRAWN - K.F. ROSKING TRACED - V.J. GREY DATE - 11-7-74	APPROVED - DRG No 9-BS-74



REFERENCES

1. Stewart, R.G. "Cutting of Wool from Sheepskins".
Wool Research Organisation of New Zealand Report 1971.
Revised October 1973.
2. Dixon J.M. and Winn A.K. "Band Knife Shearing of
Sheepskins", Final Year Project, AM/4/72, University
of Canterbury, Department of Mechanical Engineering.
3. Gillespie P. "Handling of Wool Pelts", Final Year
Project AM/1/73. University of Canterbury, Department
of Mechanical Engineering.
4. Osborne W.C. and Turner D.A. "Woods Practical Guide
to Fan Engineering". Woods of Colchester Ltd., 1952.
pp 80 - 81.
5. Timoshenko S. "Strength of Materials" Part I and II.
D. van Nostrand Co. Ltd., 1947, Part II, Ch.5.
6. Reise O.T. U.S. Patent No. 3,535,744, "Apparatus
and Method for Severing Fleece from a Sheep Pelt."
October 27, 1970.